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THE EVOLUTION OF THE AMERICAN LOCOMOTIVE.

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LADIES AND GENTLEMEN:—In the historical accounts of railroads which have been written, and which have generally been very incomplete, the process of development through which this wonderful machine was perfected in America, has never been adequately told. To do it, however, it will be essential to begin—as personal history often does—with European ancestors. It is hardly worth while, though, to repeat the history, which has been told so often, of the inventions and works of Watt, Murdock, Oliver Evans, Trevithick, Blenkinsop, Chapman, Ericsson, Stephenson and others, who are mentioned in connection with the early days of the iron horse, when it was still a mere colt. Their work, important as it was, will be passed over, as it is the purpose of the lecture to describe not how the locomotive was born, but how it grew and developed in America, after it made its early appearance on the English railroads. We will begin with the celebrated trial on the Liverpool and Manchester Railway, in 1829.

In that year, it was determined by the Director of that company to offer a premium for the best locomotive engine, which should draw, on a level plain, three times its own weight at ten miles per hour. Mr. D. K. Clark, in his treatise on *Railway Machinery*, says very truly, that "from this time, 1829, may be dated the era of modern locomotives in England," and, it may be added, in the world.

The most successful locomotive in that trial, as probably most of you remember, was the "Rocket" (*Fig. 1*), built by Robert

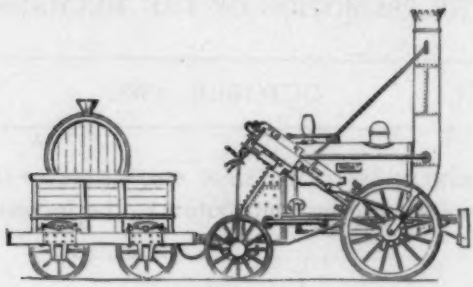


FIG. 1.

Stephenson, of Newcastle. This was the first locomotive made in England with a multitubular boiler. The trial demonstrated the superiority of that form of boiler over all others for locomotives, and it has maintained its pre-eminence ever since, with very little or no change in the principles of its construction. The value of that form of boiler, and the great advantage of the steam blast in the chimney, were established by that trial beyond all question, and all subsequent experience has confirmed this early verdict in their favor.

But before we go further, perhaps a little explanation should be given of the principles and of the construction of multitubular locomotive boilers, and some of the reasons why they are made as they are, will be presented.

You are all familiar with the ordinary phenomenon of a boiling tea kettle. In the days of our grandmothers, the method employed for boiling water was to suspend an iron or a copper kettle and then build a fire under it. Modern progress has substituted a cooking stove, with a round or oblong hole on top, over which the kettle is placed, the fire being below. You all know,—especially the ladies present, who, it is hoped, are not ignorant of such

subjects,—that cooking stoves, besides a kettle of moderate size, also have, what in domestic parlance is called a wash-boiler, which holds a very much larger quantity of water than the smaller kettle. The opening in the stove, which receives the wash-boiler, is usually oblong and much larger than that which takes the tea kettle, consequently the amount of surface in the bottom of the large kettle or boiler, which is exposed to the fire, is much greater than that of the small kettle. Experience has taught the need of this; that is, if a large amount of water must be boiled, a proportionate amount of surface of the kettle must be exposed to the fire. Or, in other words, each square inch of surface of the kettle will absorb a certain amount of heat and convey it to the water inside. Consequently, if much water is to be heated, there must be much surface exposed to the fire, because two square inches will absorb twice as much heat as one, and ten square inches ten times as much. The same principle which is applied to cooking stoves holds good also of locomotive boilers. In a locomotive, a large amount of water must be boiled and converted into steam in a short time, and the amount of space which can be occupied by the boiler is limited. The problem, in the construction of locomotives, then, was to make a boiler of a given size with the largest possible amount of surface exposed to the fire.

To meet these conditions in the "Rocket," Robert Stephenson designed a rectangular fire-place or fire-box, as it is technically called, made of metal plates, and this box had double sides and a double top, with a space between, which was filled with water. The fire was, therefore, surrounded with water, and the heat was rapidly absorbed by the plates from the fire on the one side and conducted to the water on the other.

But mention has been made of the steam blast. This is produced by allowing the exhaust steam from the cylinders to escape up the chimney. The effect is to drive the smoke and gases up the chimney, which produces a partial vacuum below. The air and smoke has a tendency to flow into this vacuum, which creates a strong draft through the fire and stimulates the combustion in the grate. When a locomotive is working hard, the air is drawn through the fire and the products of combustion are carried away from it and up the chimney very rapidly; the consequence is that there is very little time for the heat to be conveyed to the sur-

faces of the boiler. For this reason, a large number of small tubes are provided, through which the smoke and gases escape. These present a great deal of surface and are surrounded with water. The heat is thus absorbed in the inside of the tubes and communicated to the water on the outside. By this means, a large amount of what is called heating surface is provided, and, consequently, a great deal of water can be heated and converted into steam.

As already stated, one result of the trials on the Liverpool and Manchester Railway, in 1829, was that the great advantage of the multitubular boiler and the steam blast was demonstrated, and these features of locomotive construction have been in use ever since. We may then mark and emphasize this as a distinct step in the evolution of the locomotive, and we may now inquire what was the next step. Neither of the two other locomotives, the "Sansparíel" and the "Novelty," which took part in the Liverpool and Manchester trial, had any distinct features, not embodied in the "Rocket," which have survived to the present time. We may, therefore, disregard them, and see what modifications were adopted in the engines which succeeded the "Rocket." In Clark's *Railway Machinery*, it is said that "the first eight engines made by Mr. R. Stephenson for the Liverpool and Manchester Railway, were made on one general plan: four-wheel engines, tall and square, with outside cylinders in an inclined position, and working on crank-pins fixed to the driving-wheel. These engines, from their shortness and from the extreme transverse distance of the cylinder, were susceptible, at high speeds, of a violent oscillating motion, which eventually led to their abandonment."

Previous to 1830, Mr. Hackworth designed a four-wheeled engine for the Stockton Railway, with cylinders inside of the wheels and connected to cranks on the driving-axles; the four wheels were coupled together. In the early part of 1830, Mr. Berry also completed a locomotive of a similar design.

In the latter part of 1830, Mr. Stephenson built the "Planet" (*Fig. 2*), which gave its name to a whole class of engines afterwards. It had four wheels, two of which were drivers. The axles were both located between the fire-box at one end and the smoke-box at the other. The cylinders were placed in the inside of the wheels, and were connected to cranks on the driving-axle. The

cylinders of the "Rocket," as you will observe, were on the outside of the wheels, and occupied an inclined position, and one of the axles was behind the fire-box. The "Planet" engine was the combination, in part, of what had previously been known; the multitubular boiler, the blast pipe, the inside horizontal cylinders, which were placed inside the smoke-box, and the double crank-axle. It had no special features of novelty, but it represented a distinct type which was much used and was a definite step in advance. As Clark says, "the success of the arrangements combined in the 'Planet,' formed a new starting point for improvement. New locomotives were from that time formed on the model of the inside-cylinder engine, and the pattern was early imitated on other railways."

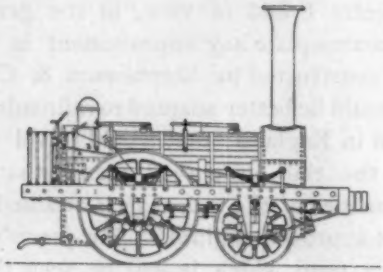


FIG. 2.

Woods's *Treatise on Railways*, published in 1838, contains a list of locomotives—beginning with the "Rocket"—built by R. Stephenson & Co. for different railroads. Among them are three for the Newcastle and Frenchtown Railroad in this country, two for the Saratoga and Schenectady, three for the Mohawk and Hudson, one for New York, one for the United States, three for the Charleston and Columbia, two for the Pennsylvania, one for Columbia, making sixteen locomotives in all which were sent to this country previous to 1838. Those sent to the Newcastle and Frenchtown Railroad, and the first ones sent to the Saratoga and Schenectady and the Mohawk and Hudson Railroad, were four-wheeled engines, and were, in all probability, of the "Planet" class. The wheels of these engines were near together, and as the wheel-base was short, they were unsteady on our rough roads. The axles were held rigidly parallel to each other, and therefore there was a lack of horizontal flexibility. To obviate these difficulties, Mr. Horatio

Allen, in a report made to the South Carolina Railroad Company, in May, 1831, made the following suggestions: "As to the change of direction, horizontally, as in the entrance of turn-outs and the passage of curves * * if we connect the frame with the cross-piece only at the centre, and by a horizontal joint the two sets of wheels will thereby be enabled to pass all curvatures with the facility of two simple wagons connected in the ordinary manner."

In the latter part of 1831, Mr. John B. Jervis recognized the defects of the English engines of the "Planet" class, which had been imported into this country for the Mohawk and Hudson Railroad, and then invented what he called "a new plan of frame, with a bearing-carriage, for a locomotive engine." He described this invention, in a letter to the *American Railroad Journal*, as follows: "The leading objects I had in view, in the general plan of the engine, did not contemplate any improvement in the power over those heretofore constructed by Stephenson & Co., but to make an engine that would be better adapted to railroads of less strength than are common in England; that would travel with more ease to itself and to the rail on curved roads; that would be less affected by inequalities of the rail, than is attained by the arrangement in the most approved engines." Mr. Jervis's engine is represented by *Fig. 3*, from which it will be seen that the driving-

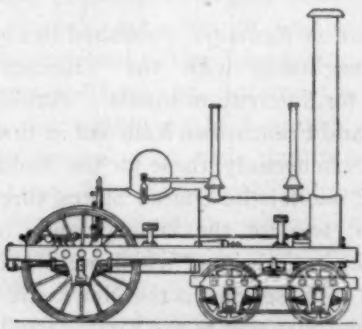


FIG. 3.

wheels were placed behind the fire-box and boiler. Other locomotives were built soon after with the driving-wheels in front of the fire-box, as shown in *Fig. 4*. The difficulty with these two classes of engines was that the driving-wheels carried too small a proportion of the weight when they were behind the fire-box, and

they had too much on them when they were in front. To obviate the latter difficulty, the locomotive shown in *Fig. 5* was con-

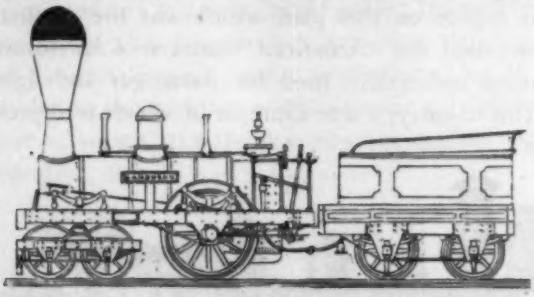


FIG. 4.

structed, with a pair of trailing-wheels behind, which thus diminished the load on the driving-wheels; it also lessened their adhe-

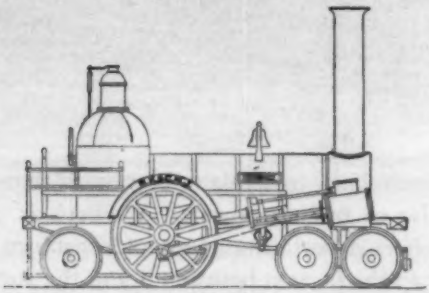


FIG. 5.

sion or the friction of their wheels on the rails, and thus made them liable to slide their wheels. In 1836, Mr. Henry R.

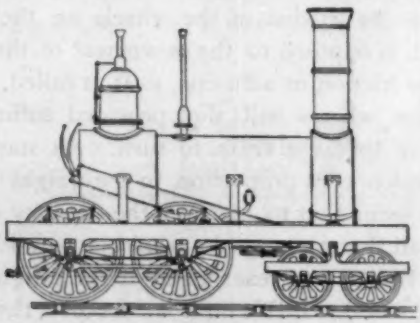


FIG. 6.

Campbell, of this city, patented the duplication of the driving-wheels, as show in the illustration, *Fig. 6*. That is, he placed one

of the driving-axles in front of the fire-box and another one behind, with a swivelling-truck in front. He subsequently constructed an engine on this plan, which was the original type of what is now called the "American" pattern of locomotive, which is now almost universally used for passenger and light freight service in this country, a late example of which is represented by *Fig. 7.*

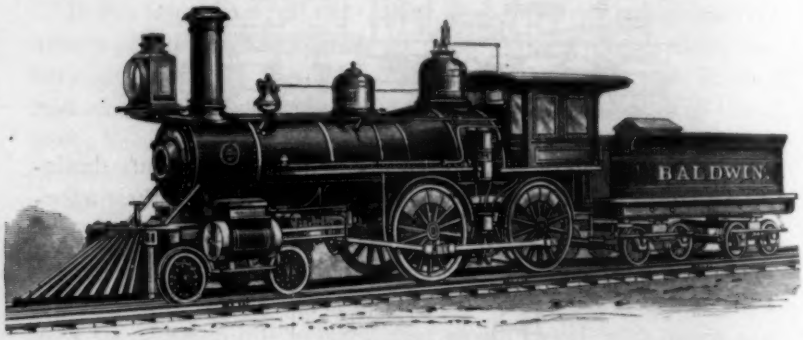


FIG. 7.

It may be well here to explain how it is that a locomotive exerts its tractive or pulling power. A wheel, as you all know, when loaded, offers a certain amount of resistance to sliding or slipping, owing to the friction between it and the surface on which it rests. This friction is in proportion to the load on the wheel. If the wheels of a locomotive are made to revolve, the whole machine moves forward, and will thus exert a tractive or pulling power, equal to the friction of the wheels on the rails. If the resistance which is opposed to the movement of the locomotive is greater than the friction or adhesion, as it is called, of the wheels to the rails, the wheels will slip, provided sufficient power is applied to them to cause them to turn. As stated before, the friction or adhesion is in proportion to the weight on the wheels. At first it may seem that to increase the capacity of locomotives to draw loads, all that we need do, would be to add to the weight of the wheels. But we can reach a limit to the weight which can be carried on each wheel. If this limit is exceeded, then the rails and road-bed are crushed, so that if we want to increase the capacity of locomotives beyond a certain point, we must add to the number of driving-wheels, so as to distribute the weight of the locomotive

on more points. It was this consideration which led Campbell to adopt two pairs of driving-wheels in connection with a truck. As traffic increased and trains became heavier, it was found, especially on steep grades, that locomotives with four driving-wheels only, were not powerful enough for the work demanded of them. This naturally led to the addition of still another pair of driving-wheels, the result of which was the ten-wheeled engine, represented by the illustration, *Fig. 8*.

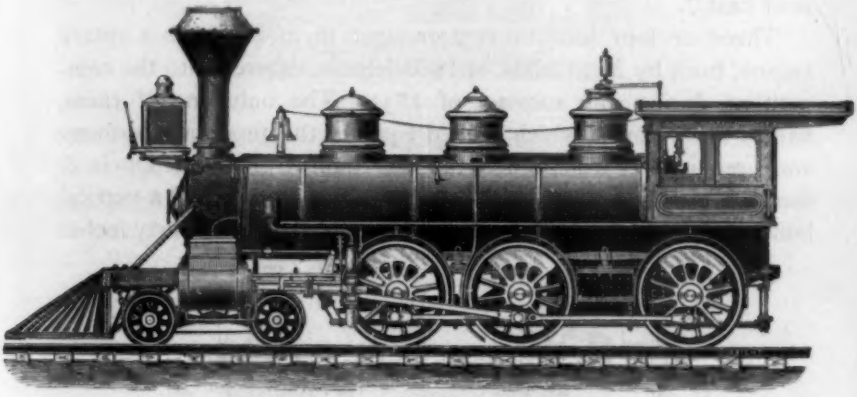


FIG. 8.

Locomotives as we find them to-day, in this country, are the result of a course of development, which has moved not in one line only. There have been different streams which have advanced for a time separately, and eventually have, as it were, flowed into each other. Thus, one of the earliest railroads in the country was the Baltimore and Ohio, and it was one of the first lines on which

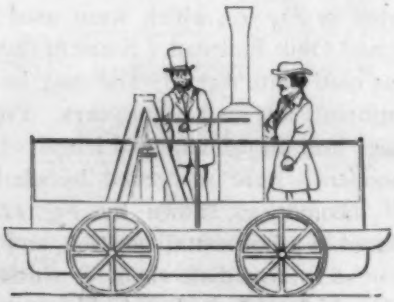


FIG. 9.

locomotives were used. As early as 1829 and 1830, Mr. Peter Cooper experimented with a little locomotive, *Fig. 9*, on that road. His

engine never advanced beyond the experimental stage, however. The story of how it ran a race with a gray horse, and was beaten by the beast, has been told a great many times and need not be repeated here.

In January, 1831, the Baltimore and Ohio Railroad Company offered the sum of $4,000 "for the most approved engine which shall be delivered for trial upon the road, on or before the 1st of June, 1831, and $3,500 for the engine which shall be adjudged the next best."

Three or four locomotives, amongst them one with a rotary engine, built by Mr. Childs, of Philadelphia, entered into the competition during the summer of 1831. The only one of them, named the "York," which proved equal to the moderate performance required of them, was the one built by Messrs. Davis & Gartner, two machinists of York, Pa. The engine had a vertical boiler and vertical cylinders, with four coupled wheels, thirty inches

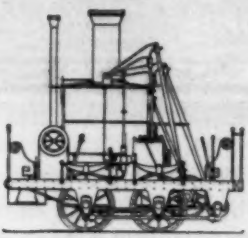


FIG. 10.

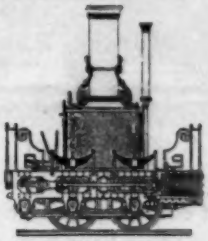


FIG. 11.

in diameter. It was altered considerably after being placed on the road. The "Atlantic" was afterwards built by the same firm, and was the first of what were afterwards known as the "Grasshopper" engines, represented by *Fig. 10*, which were used for many years on the Baltimore and Ohio Railroad. Some of these engines were still in use on that road quite recently and may be yet. Some of them were in continuous service for fifty years. Probably no other locomotive has ever been in use an equal length of time.

The "Grasshoppers" were succeeded by what was known as the "Coal-crab" locomotives, shown by *Fig. 11*. In this, the cylinders were placed in a horizontal position, and they were connected to cranks in an intermediate shaft *G*, which was geared to a second shaft *H*, which also had outside cranks to which the driving-wheels were coupled. The vertical boiler was retained in these engines.

The need of more powerful locomotives, on the heavy grades of the Baltimore and Ohio Railroad, led Mr. Winans to build some engines with eight wheels coupled, as represented by *Fig. 12.*

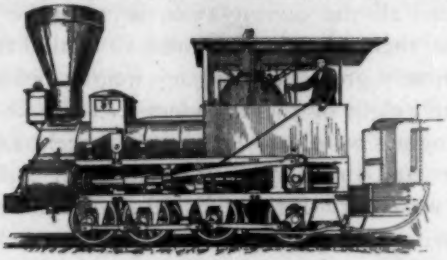


FIG. 12.

In these, the vertical boiler was abandoned, and one with horizontal tubes was substituted. The cylinders were still connected to an intermediate shaft, which was geared to one of the driving-wheel

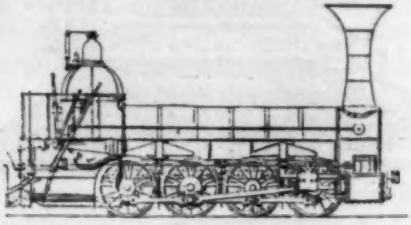


FIG. 13.

axles. The frames, it will be noticed, were outside the wheels, a form of construction which is still retained in Europe.

These machines were ignominiously named "Mud-digger"

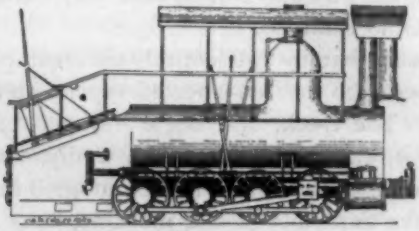


FIG. 14.

engines, and were succeeded by what was known as the "Camel" engines, two forms of which are shown in *Figs. 13* and *14*. A large number of them were built by Mr. Winans for the Baltimore and Ohio, and other roads. When these were designed, the inter-

mediate driving-shaft was abandoned, and the cylinders were connected direct to the driving-wheels. Mr. Winans was one of the earliest builders to recognize the value of a large grate and fire-box. He placed all the driving-axles between the fire-box and smoke-box, and then extended the fire-box behind the rear axle; this resulted in very great overhanging weight behind, which he balanced by the weight of the cylinders and smoke-box in front. While these engines were very long, their wheel-bases were comparatively short, and therefore they would enter and pass around sharp curves with very little difficulty. They were generally regarded as having a propensity for leaving the track at inopportune times, and this led to the adoption of a form of ten-wheeled engine, *Fig. 15*, which was designed by the late Mr. Hayes, who

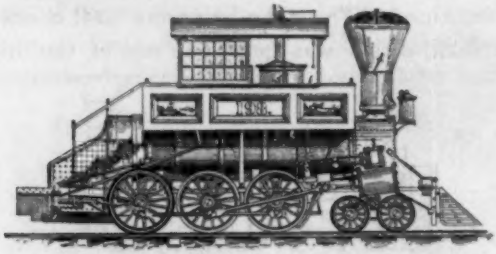


FIG. 15.

was for a number of years master of machinery on the Baltimore and Ohio Railroad. These engines had a truck in front, which extended the wheel-base, and the fire-box was made shorter than that of the "Camel" engines, so that there was less overhang behind. This type of engine was, and still is, used very extensively on the Baltimore and Ohio Railroad.

It will be seen that by two entirely different paths the locomotive developed into the ten-wheeled type, with a four-wheeled truck in front. The truck, or "bogie" system, as the English engineers call it, was for a long time a distinctive feature of American locomotives and cars. It was adopted in the first place in order to give flexibility to the machine, thus enabling it to adjust itself to the uneven and crooked roads in this country. A truck as ordinarily made, consists of two pairs of wheels, attached to a rectangular frame, which is connected by a "centre-pin" to the engine, so that the truck can turn around this pin as the front axle of an ordinary wagon swivels about its king-bolt.

It will require no explanation to show how this arrangement acts in running around curves. From the illustration of ten-wheeled locomotives, *Fig. 8*, it will be seen that one pair of the truck-wheels comes immediately behind the cylinders. This makes it essential that the front pair of driving-wheels should be placed back of the truck-wheels far enough at least to give room for the latter. The result is, that a considerable part of the weight of the locomotive rests on the truck, and the weight on the driving wheels is diminished to that extent. This lessens the adhesion of the driving-wheels, and the capacity of the locomotive to pull loads. It may be thought, at first, that a truck might be made consisting of a single axle, pivoted to the engine in the same way that an ordinary axle is attached to a wagon. It must be remembered, though, that a wagon or carriage-axle is always guided and controlled by the tongue or shafts, and if any of you have ever tried to push a carriage or other four-wheeled vehicle, when the tongue or shafts are removed, you know how difficult it is to control the movement of the front wheels and axle, and to guide the movement of the vehicle. Notwithstanding that railroad wheels are guided and kept in place on the rails by flanges, a single axle, if pivoted to a locomotive, as a wagon-axle is to a wagon, would be uncontrollable, and as our friends and fellow-citizens in New England would say, the axle would "slew" around and the wheels would not stay on the rails. To get over this difficulty, Mr. Levi Bissell invented, and in 1857 patented, a two-wheeled truck. He attached a single pair of wheels to a triangular-shaped frame and pivoted the apex of the triangle to the locomotive. The weight of the locomotive rested immediately over the axle on inclined planes, on which the locomotive frame could slide laterally. Afterwards Mr. Alba F. Smith suspended the engine over the axle by swing links, and this plan is now quite generally used.

The Bissell truck made it possible to dispense with one pair of the wheels of a truck, and the consequence was a locomotive constructed with the wheels arranged as shown in *Fig. 16*, with the front driving-wheels close to the cylinders, and with a single pair of truck-wheels on the Bissell plan in front of the cylinders. The first locomotive of this kind that was built was called the "Mogul," which gave the name to this whole class of engines, and they are now universally known as "Mogul" engines.

It will be remembered that Winans's "Camel" locomotives had eight coupled wheels. This gave them a great advantage, owing to the fact that the whole weight was on the driving-wheels, and that they therefore had the maximum amount of adhesion. Such engines would therefore pull enormous loads, but, as stated before, they were unpopular, because they were considered dangerous owing to their comparatively short wheel-base, and the large amount of overhanging weight at each end. On the other hand, the ten-wheeled engines had a considerable proportion of their weight on the trucks, which resulted in a corresponding reduction of their power. The trucks of the "Mogul" engines carried a smaller proportion of the weight, which gave them some advantage over the ten-wheeled type. Neither kind had more than six driving wheels, so that the weight which could be utilized for producing adhesion could not exceed six times that which could be carried

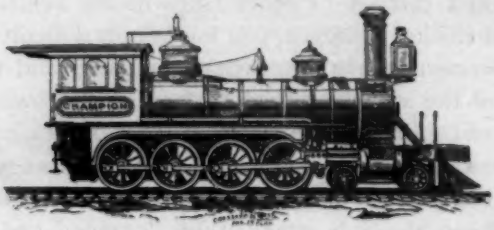


FIG. 18.

on one wheel. This naturally led to the addition of another pair of driving-wheels to the "Mogul," and the ten-wheeled engines, when more powerful locomotives were required, from which resulted the type shown by *Fig. 17*. The "Mogul" engines was thus converted into the "Consolidation" engine, and, with another pair of driving-wheels, the ten-wheeler was changed to what has been called the "Mastodon" locomotive, *Fig. 18*.

It will thus be seen that the process of evolution has developed first, what has been called the American type of locomotives, with four driving-wheels, and a four-wheeled truck, next, ten-wheeled and "Mogul" engines each with six driving-wheels, one of them with a four and the other with a two-wheeled truck; and third, the "Consolidation" and "Mastodon" engines, each with eight driving-wheels and two-, and four-wheeled trucks, respectively. These are now the principal types of locomotives on American railroads. There have

been a good many collateral branches to this family, but it will not be possible to follow out the genealogy of all of them. One branch is perhaps deserving of attention here. Even before the days of the "Rocket" and the "Planet," locomotives were built with four wheels, all drivers, and all coupled. Such machines have the advantage, that all their weight is carried on the driving-wheels, and consequently they have the maximum amount of adhesion. But, in order to pass around curves easily, such locomotives must have their wheels comparatively near together. Such engines are, therefore, lacking in stability and steadiness, especially at high speeds or on rough roads. Nevertheless, the advantage of utilizing the whole weight for producing adhesion is so great, and the evil of unsteadiness is not of much importance at slow speeds, that such engines have always been used a great deal for slow service like switching or drilling cars at stations, for urban and suburban traffic, etc. *Fig. 19* represents such a machine. It should be explained, perhaps, that all the locomotives which have been described are provided with tenders for carrying fuel and water. These tenders are coupled to engines with links and pins in the usual way. The switching engine shown by *Fig. 19*, it will be noticed, has all its weight on the driving-wheels, and therefore has the capacity of drawing a heavy load in proportion to its weight. As explained, it has the disadvantage of a short wheel-base and consequent unsteadiness. Some years ago, it occurred to the person who has the honor of addressing you, that if the frames of a four-wheeled locomotive were extended backward far enough to receive and carry a water-tank and fuel-bin, and if the extended frames were then supported on a truck, as shown in *Fig. 20*, that a locomotive of this kind would have all the advantages of the four-wheeler, and at the same time would have a long and flexible wheel-base with the consequent steadiness of the American type of engine. That is, all the weight of the boiler and machinery would be available for producing adhesion, and the engine would, at the same time, have a long wheel-base adapted for passing through curves easily, and in fact, have all the good points of the four-wheeled and the American engines combined. The plan was patented about twenty years ago, and now that the patent has expired, engines of this kind are coming into very general use. The New York and Brooklyn Elevated Railroads are equipped almost

entirely with them, and even in conservative Boston, the railroad master mechanics at a recent public meeting, declared that this kind of engine was better adapted than any other for suburban traffic.

I have now explained the successive steps by which American locomotives have advanced. I have not entered into details, but have confined myself to a description of its evolution more as a vehicle than as a machine, if such a distinction can be made. There are, however, some other features in the design and construction of American locomotives, which have had a great deal to do with their success under the conditions which they had to work. Many railroads in the country were not only very crooked horizontally, but in their early days were crooked, so to speak, vertically. The truck gave the engine flexibility laterally, but, on our rough roads, it remained to give it vertical flexibility. Campbell's first locomotive, with four driving-wheels, and a four-wheeled truck, was not successful. Its failure has since been attributed to the absence of any arrangement for equalizing the weight on the driving-wheels. Over the bearing of each driving-wheel a spring was placed which supported the weight that rested on the wheel. If one of the wheels ran over a high place on the line, the spring over the wheel was unduly compressed, and that wheel would then carry more than its proportion of weight, and the other wheels less. The reverse action would occur if any of the wheels encountered a depression in the track. On the early uneven and unballasted roads this was a matter of very great importance. The evil was probably exaggerated, too, by a lack of flexibility and elasticity in the springs. This evil led to the introduction of equalizing levers on American locomotives, very soon after Campbell's engine was constructed. These levers consist of a balance-beam or lever *A*, *A*, *Fig. 21*, which is placed between the two

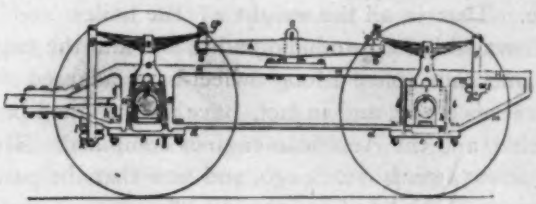


FIG. 21.

adjoining springs, *B*, *B*. The lever has a fulcrum at *C*, which is usually in the middle of the lever, and the ends of the springs are

suspended from the ends of the lever by straps or hangers *D*, *D*. The opposite ends of the springs are connected to the frame of the engine by similar straps *g*, *g*. When one of the springs is compressed, one-half of the tension in it is transferred to the strap connected to the equalizing lever, by which it is carried to the end of the other spring, and through it, to the driving-wheel below it. In this way if one of the wheels encounters either a depression or an elevation on the track, the inequality of weight carried by the two wheels is at once equalized by the action of the springs and levers. Besides this advantage, it has another, which can be explained best by a very homely illustration. You have all noticed probably that a three-legged stool or tripod of any kind, will rest securely on a floor or other surface no matter how uneven it is, whereas a four-legged chair will be unsteady if the legs are supported by four points not in a plane. The same principle applies to a locomotive or other vehicle. You know a wagon rests on its two hind wheels, but the body in front is supported in the centre of the axle, so that the latter can oscillate more or less on that point. American locomotives are arranged very much in the same way. The back end is supported on the fulcrums of the equalizing levers, and the front end rests on the centre of the truck. It is thus practically supported on three points, and therefore it can adjust itself perfectly to the vertical inequalities of the road-bed just as a three-legged stool would adjust itself to an uneven surface.

A similar arrangement of equalizers is used, with engines having six and eight driving-wheels. In such machines, especially when a two-wheeled truck is used, there is danger that at times the truck may not carry its proper proportion of weight. To meet this, Mr. Hudson, formerly the Superintendent of the Rogers

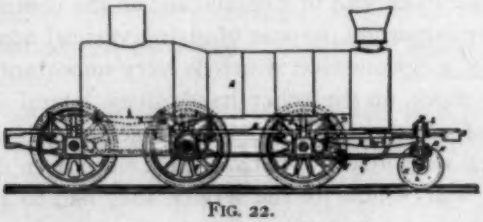


FIG. 22.

Locomotive Works, in Paterson, N. J., invented and patented an arrangement of equalizing levers, shown by *Fig. 22*. Such levers

were placed between the front driving-wheels and the truck. In his patent specifications, Mr. Hudson said: "If tracks could be made perfectly uniform and regular, and be maintained in that condition, my invention would be of little importance; but in practice, irregularities, more or less serious, occur at nearly every joint or junction of the ends of the rails, and at certain points in the track, as in passing switches and across tracks; and especially in passing over small obstacles or defects in the road, the inequality in the load, which is thrown upon the several wheels, becomes immense, unless, in addition to the use of springs, provision is made by introducing equalizing levers in some manner, to induce a unity of action between each pair of wheels and some other pair. The three pairs of drivers, *E*, *F* and *G*, have been connected together by equalizing levers; but I have never known the two pairs, *E*, *F*, to be connected together into one system, and the forward drivers *G*, to be connected to the truck-wheels, so as to form another and independent system, previous to my invention.

"My invention practically supports the forward portion of the structure at the point *k*, and the rear portion of the structure on the two points *i*, *i*, opposite the sides of the fire-box, thus making a triangle, on which the structure is carried, with a certainty of holding each wheel with sufficient force upon the track, and yielding easily and safely to every ordinary inequality."

This system has been applied to various types of engines, with Bissell trucks, and has much to do with their successful working. The use of equalizing levers has been a feature peculiar to American locomotives. European locomotive builders have aimed to secure a uniform distribution of weight on the wheels, by using long and flexible springs, but the merits of equalizing levers has been recognized by them of late years, and now they are applied to many locomotives both in England and on the continent. They serve the very important purpose of giving vertical adjustability to the wheels of a locomotive, which is very important on uneven roads. The truck, on the other hand, gives lateral flexibility to the system of wheels which carry the machine. It is these two features which were first adopted and have since been developed in this country, and which, for the service they had to perform, has given to American locomotives their superiority over those built in Europe.

The enormous increase in the weight of locomotives is not the least remarkable feature of their evolution. The "Rocket" weighed less than 10,000 pounds. At present, engines weighing over 100,000 pounds are not uncommon, and it is probable that the limit is not yet reached. But there are indications that another advance in the process of evolution must be taken, if the increase of the size and weight of locomotives continues. The gauge of railroads was, unfortunately, and to some extent by accident, made 4 feet 8½ inches. This was very well suited for the construction of engines of ten, twenty or even thirty tons weight, but when we get up to fifty tons, there is difficulty in getting room enough for a fire-box and boiler of sufficient capacity to supply steam for so large an engine. The standard distance between the flanges of the wheels for a 4 feet 8½ inches gauge road, is 4 feet 5⅜ inches. With the frames between the wheels and fire-box, the latter cannot exceed about 3 feet 8 inches in width. Therefore, in order to get a large fire-box, it must be made so long, that it becomes difficult to manage the fire. This has led a number of designers to devise plans which will permit the use of a wider fire-box than the limits named. Notably among these designs is that of Mr. Wotten of the Philadelphia and Reading Road. Probably most of you are familiar with his engines, so that no other description is needed than to say that he places the whole fire-box and grate above the wheels, which permits them to be extended laterally to any desired width. These locomotives, as most of you know, have been very effective in burning anthracite coal.

Precisely what form the locomotive of the future will take, it would be unwise to predict, but there are many evidences that the largest locomotives have nearly or quite reached the limits of size and capacity possible with the present plans of construction.

A good deal of speculation has been indulged in of late, in some of the technical papers, about the rate of speed which is attainable on our railroads.

For years past we have been told we would soon travel by rail at a speed of 100 miles an hour, if not faster; but the world has waited in vain for the fulfilment of this prophecy. To-day we are travelling faster than our fathers did twenty-five years ago, and it is a matter of wonder now, as it was then, when a speed of sixty miles an hour is maintained for any considerable time. There

must be some reason for this limitation of speed. Why is it that a locomotive can be made to run so fast, but refuses to be urged much faster? It is apparently in vain that the safety valves are screwed down, and the steam pressure increased or the wheels enlarged. Like the speed of a horse, when it reaches the traditional 2·40, it is exceeded only by the rare animals.

Persons who have only a slight acquaintance with the theory and the construction of locomotives, are apt to reason about this question somewhat as follows: It is not an uncommon thing, they say or think, for a thirty-ton engine with five foot wheels, to attain and maintain for a considerable distance a speed of fifty miles per hour and pull a train of, say, six cars. From these data, they will argue further, that if the wheels were doubled in size, all the other parts remaining the same and working the same; that is, the boiler making the same quantity of steam and the pistons an equal number of strokes, the speed would be doubled and the tractive or pulling force halved. In other words, the engine would run 100 miles an hour, and would pull three cars instead of six. Alas, for this theory! no one has ever run 100 miles an hour, or is likely to soon.

In the language of the immortal and genial Artemus Ward, one might ask, "Why is this thus?" There must be a fallacy somewhere. Our locomotive and its tender would weigh 100,000 pounds and each loaded car would weigh 50,000 pounds, so that the weight of the whole train would be 400,000 pounds. Now, be it observed, the load which a locomotive draws is its own weight *and* that of the cars; so that if the tractive or pulling power of our engine, when mounted on ten-foot wheels, is halved, the load it would pull would be only 200,000 pounds, or its own weight and two cars. This is on the assumption that the resistance of the train is the same at 100 miles per hour that it is at fifty. Unfortunately for the prophets again, there is a very great divergence of what may be called the line of this assumption and the actual facts. It must be admitted, though, that we do not know certainly what the resistance of trains is at high speeds, and, our knowledge of the resistance at any speed is still very imperfect and inaccurate. It seems to be uncertain, even, whether the law laid down in most of the text books that the resistance of the atmosphere increases as the square of the velocity, is true.

The article on "Gunnery," in the new *Encyclopædia Britannica*, contains the following statement:

"The resistance of the air to slow movements of, say, ten feet per second, seems to vary with the first power of the velocity. Above this the ratio increases, and, as in the case of the wind, is usually reckoned to vary with the square of the velocity; beyond this it increases still further, till at 1,200 feet per second the resistance is found to vary as the cube of the velocity. The ratio of increase after this point is passed is supposed to diminish again; but thoroughly satisfactory data for its determination do not exist."

To explain this in less scientific phraseology, the resistance of the atmosphere at a speed of 100 feet per second would be four times as great as it would be at fifty feet per second; or, in other words, if you double the speed, you increase the resistance four times, and at sixty miles an hour, the atmospheric resistance is about nine times as great as it is at twenty miles an hour. As indicated by the gunnery experiments, atmospheric resistance at higher speeds, probably increases in a still greater proportion. Although the resistance of the atmosphere is a comparatively small proportion of the resistance of railroad trains at slow speeds, it is a very important element at high speeds. The experiments in gunnery indicate, though, that at high speeds it is considerably greater than is ordinarily supposed.

There is no time, nor is this the place, to follow out these calculations further. It may be said though, that not only is the power required to pull a train at a high speed very much greater than at a slow one, but the steam which exerts this power must be generated in less time. That is, much more steam is required and must be produced in a shorter time than the smaller amount of steam was generated in before. Obviously this makes an immense boiler capacity essential, which adds to the dead weight to be hauled, and to the difficulty of pulling the train.

These and other considerations lead to the conclusion that we have very nearly reached the practical limit of speed of trains, unless some radical improvements shall be made in the motive-power employed. The fact, too, that twenty-five years ago locomotives ran very nearly if not quite as fast as they have since, notwithstanding the improvements which have been made in their

manufacture and construction, indicates that there are some physical laws which place a limit on the number of miles per hour that a locomotive can run. But even if there be such a limit, it does not diminish the wonderful results which have been wrought by this most fascinating of all machines. The secret of this fascination is not hard to explain. You can all remember the immense difference there was in your youthful minds, between a watch which would *go*, and one which would not. Perhaps none of you are too old, and certainly none are too young, to take delight in a chip, which by virtue of a bit of muslin or paper is converted into a ship, or to be pleased with a miniature water-wheel or wind-mill. They all have the element of *go* to them. But no human invention or creation is this *go* manifested in so impressive a way as it is by a locomotive.

I may repeat here what De Pambour wrote, more than fifty years ago, in the introduction to his treatise on *Locomotive Engines*, in which he said:

"We have studied the subject with all the interest, and we might say, with all the enthusiasm it excited in us. In fact, what a subject for admiration is such a triumph of human intelligence! What an imposing sight is a locomotive engine, moving without effort, with a train of forty or fifty loaded carriages, each weighing more than 10,000 pounds! What are henceforth the heaviest loads, with machines able to move such enormous weights? What are distances, with motors which daily travel thirty miles in an hour and a half? The ground disappears, in a manner, under your eyes; trees, houses, hills, are carried away from you with the rapidity of an arrow; and when you happen to cross another train travelling with the same velocity, it seems in one and the same moment to dawn, to approach and to touch you; and scarcely have you seen it with dismay pass before your eyes, when already it is again become like a speck disappearing at the horizon."

In the introductory preface to his *Treatise on Railway Machinery*, Mr. Daniel Kinnear Clark says: "The locomotive, naturally, was my chief object of study; and to the investigation of that admirable machine, its construction, its working and its performance, my attention principally was directed. I may add that the peculiar union of beauties, mechanical and æsthetical, to be found in the locomotive—the association of compact, concentrated,

mechanical action with freedom and elegance of form, and with the most graceful of movements—made me conscious that there was not alone a theorum to investigate, or a problem to solve, but an object, besides, of enduring admiration," which is a feeling I am sure you will all share, the longer you study this wonderful machine.

THE GREAT BRUSH DYNAMO.

A DESCRIPTION OF THE GREAT DYNAMO-ELECTRIC MACHINE BUILT BY THE BRUSH ELECTRIC COMPANY FOR THE COWLES ELECTRIC SMELTING AND ALUMINUM COMPANY WITH AN ACCOUNT OF TRIAL TESTS MADE OF THE MACHINE.

BY DR. ROBT. H. THURSTON, Director Sibley College, Cornell University.

[*Read at the Buffalo Meeting of the American Association for the Advancement of Science, August 19, 1886, and Revised for Publication in the* JOURNAL *by the Author.*]

The process of reduction of aluminum and other metals, and production of alloys, invented by Messrs. Eugene H. and Alfred H. Cowles, and perfected with the assistance of Professor Mabery, of Cleveland, O., has attracted the attention of engineers, as well as of men of science, not only on account of the ingenuity, simplicity, and effectiveness of the process itself, but also, and probably quite as much, because of its bringing into use the voltaic arc and dynamo-electric machines of exceptional and enormous power.

The writer, on the occasion of a recent trip to the West, was, on his return journey, so fortunate as to be able to stop in Cleveland long enough to witness the operation of the process, and to be present at the first trial of the great dynamo recently completed by the Brush Electric Company for the Cowles Electric Smelting and Aluminum Company. The occasion was so interesting, and the facts developed so striking and probably important, that it has been thought worth while to present a very brief account of them to the members of this section of the American Association for Advancement of Science.

The Cowles process, as will be remembered by those who

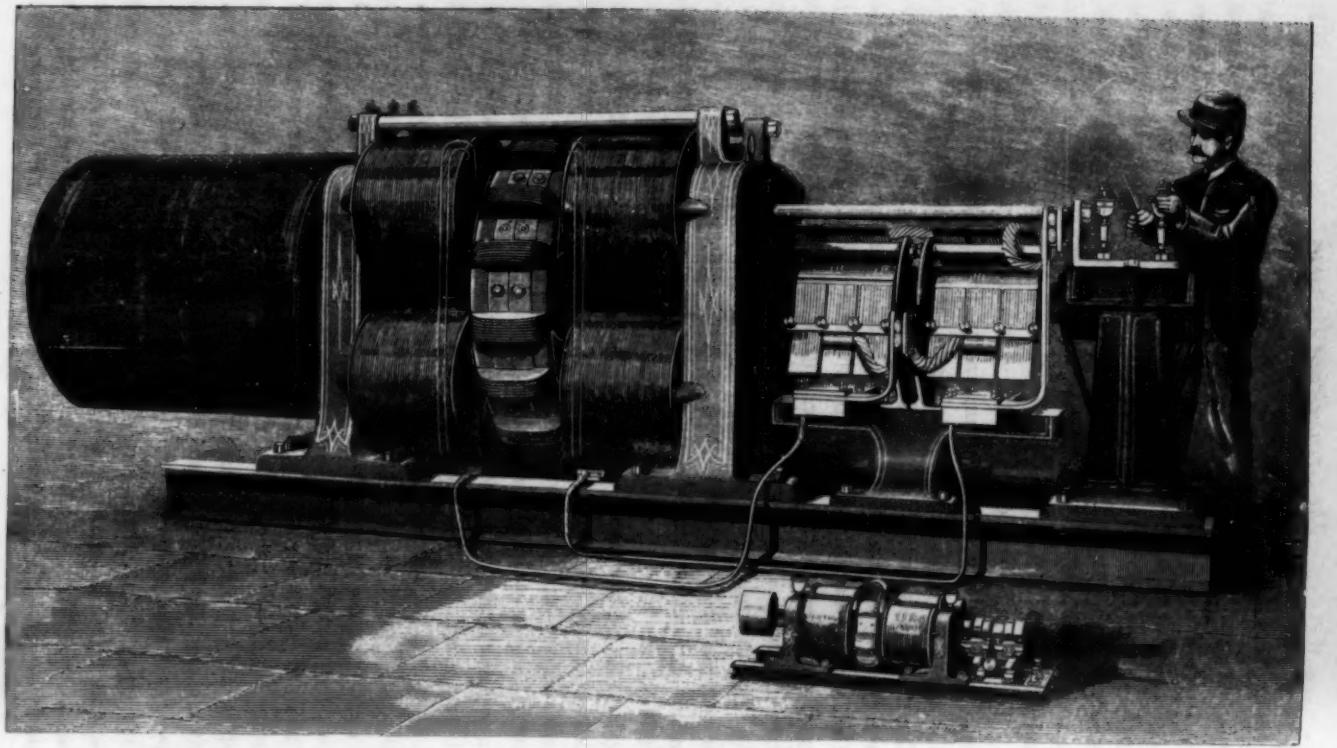
listened to the interesting account given the association at the Ann Arbor meeting of 1885, and published in the *American Journal of Science* for October of that year, or who have read the interesting paper of Mr. Eugene H. Cowles, read at the stated meeting of the FRANKLIN INSTITUTE, in January, 1886, and published in the JOURNAL for February, 1886, consists in the passage of a powerful current of electricity from a "dynamo" through a mass of ore mixed with carbon and other material forming the "charge," until the action of the heat, and possibly of the electrical force, causes a reduction of the ores and the formation of an alloy of the metals so reduced. The apparatus consists simply of a powerful dynamo-electrical machine, connected with a pair of carbon electrodes of correspondingly exceptional size, these electrodes being enclosed in a furnace of brickwork, lined with the most refractory available material. The Cowles Company have several dynamos, all of large size, but it is the intention of the writer to describe but one, the latest built and the largest. The next smaller, which was until recently considered a very powerful machine, weighs about two tons and a-half, is driven at 900 revolutions per minute, and produces a current of 1,575 ampères, with an E. M. F. of forty-five volts. These machines are "shunt-wound" and very nicely proportioned under the direction of the inventor, Mr. Charles F. Brush, whose interest in the work induced him to give to this construction his personal attention. The largest machine, recently completed, and under test at the time of the visit of the writer to the works, weighs 21,900 pounds, (9,934 kgs.) a so-called 42-inch (1060·6 mm.) machine, the armature having that diameter. The armature contains 1,600 pounds (725·7 kgs.) of iron; it carries 825 pounds (378 kgs.) of copper wire, while the field magnets are wound with about six times that weight, 5,424 pounds (2641·8 kgs).

The armature of this great dynamo consists of sixteen bobbins, each carrying twenty-one turns of best copper wire, two strands lying side by side, the wire being 0·35 inch in diameter (8 89 mm). These sixteen bobbins are operated in multiple arc, thus giving thirty-two strands of copper wire of the diameter above stated, and about sixty-five feet (19·8 m.) long. Sixteen copper bars carry the current from the bobbins to the commutator, each bar being one inch by one-half inch (25·4 mm. by 12·7 mm.) in section. The two commutators are coupled in multiple arc.

The field magnets are eight in number, and consist of a cylindrical cast iron core, 11 inches (279·4 mm.) in diameter, by 16 inches (406·4 mm.) in length, and wound with thirty layers of one hundred and two turns, each, of copper wire, 0·134 inch (3·404 mm.) in diameter; all the eight wires are coupled in multiple arc as in a shuntfield. Thus combined they have a resistance of about one ohm, total, cold. The pole pieces are of peculiar form, and fitted carefully to the field.

The driving shaft, carrying the armature, is 13 feet (3·962 m.) long, and 5½ inches (139·7 mm.) in diameter in the main bearing; it is made of open hearth steel, furnished by the Otis Company. The machine is driven by means of a 44-inch (1117·6 mm.) double belt, turning a 40-inch (1,016 mm.) pulley on the armature shaft. The machine occupies a space on the floor about 15 feet (4·572 m.) long, and 4 feet (1·219 m.) wide, and stands about 5 feet (1·52 m.) high.

This dynamo was calculated to furnish a current of 3,200 ampères, with an electro-motive force of eighty volts, with a normal maximum current in the field of eighty ampères; the speed of rotation not to exceed 600 revolutions per minute. Its actual speed was a little above 400 when doing the full amount of work demanded. The maximum field is thus obtained with but about two and one-half per cent. of the normal current (3,200 ampères), and falling to one per cent. when less E. M. F. is needed. When in operation, the writer found no observable heating in any part of the machine, and the bearings ran perfectly free from heating or cutting. The efficiency of the machine must be very great, as, after its longest run of two hours, the armature was cool enough to handle with perfect comfort. The writer could bear his hand on every accessible part of the machine, which included all parts liable to any serious heating. The belt was new and stiff, and occasionally slipped as the limit of the power of the machine was approached; but that was a fault which a little work would cure, by making the belt flexible and giving it a better bearing on its pulleys. Had the engine driving it been of sufficient power, it was evident much more work could have been done than was actually performed on the trial. It was judged that it might have been driven up to 300,000 watts with safety. The conductors provided, and the resistance coil used in measuring the power



The Great Brush Dynamo.

developed, were, however, about at the limit of their endurance. As it was, the former heating until they were blue, and the latter requiring constant watching and cooling by application of water. The maximum reached was 249,000 watts, or 334 electrical horse-power, the engine probably developing not far from 400 indicated horse-power. No indicators had been fitted, and it was impossible to measure this factor. The limit of its power was reached, however, and the power of the dynamo could not be tested to its maximum The speed intended was, for the dynamo, 430 revolutions, but at eighty volts it could not be driven by the engine up to that speed.

The dynamo was built, complete, in all its details, from the specifications of Mr. Brush, and without preliminary experiment, and, when tested, was found to require no alterations of any kind, and came fully up to the requirements of the specifications and contract. Its capacity is very much greater than that of any machine yet built in the United States, or in the world. Its successful construction is considered by its designer to indicate that it is possible to design a machine of any desired size and power, with perfect confidence that it will come fully up to the calculated performance. No limit is to be seen, as yet, to the size and power of the machines, if properly designed. Their construction is a matter of definite calculation, and is to-day independent of direct experiment. The fact that a dynamo may be precisely designed and proportioned for any kind and amount of work that may be demanded, for any purpose whatever, without limit, so far as can be to-day perceived, is one of the most interesting and important revelations of recent work in this field. The fact, also plainly shown by the experience of the Cowles Company, in the use of these enormous machines, that the larger the machine, the higher the duty of the plant, is no less interesting and important. The economy secured in the production of their aluminum and other alloys, by the increased size of the later dynamos put in operation, is so great as to be a very valuable factor in the operation of the business, each new and larger machine very considerably reducing the price at which the metals can be put on the market.

EXPERIMENTS WITH 42-INCH BRUSH MACHINE. JUNE 25, 1886.

Revolutions per Minute.	E. M. F. Volts in Ext. Circt.	Ampères in Ext. Circt.	Ampères in Field Shunt.	Watts in External Circuit.
428	78	1,000	33¼	78,000
424	68	2,000	30⅛	136,000
423	56	2,500	27½	140,000
420	66	2,600	37½	171,600
418	72	2,640	46½	190,080
410	76	2,700	58	205,200
420	94	2,040	89	191,760
412	88	2,450	85	215,600
410	86	2,700	83	232,200
410	85	2,800	82	238,000
405	83	3,200	80	249,000
423	56	2,700	29	151,200
423	54	3,150	35	170,100
423	62	3,400	45	210,800
423	66	3,400	50	224,400
423	68	3,400	52	231,200
423	52	3,000	33	156,000
421	46	2,950	28	135,700
421	36	2,620	21½	94,320
421	32	2,500	19	80,000
421	26	2,300	16	59,800
421	22	2,100	15	46,200
421	19	1,850	13	35,150
431	100	0,000	76	
431	105	0,200	100	

The tabulated statement shown, herewith, presents the figures obtained at the trial of the ten-ton dynamo above described, and will repay careful study, as they exhibit the effect of variation of speed, of variation of current in the fieldshunt, and of electro-motive force, in the production of energy in the external circuit. The highest power attained on this occasion was, as shown in line 11 of the table, 249,000 watts, the speed of revolution being 405 (twenty-five turns below the regular speed), the electro-motive force being eighty-three volts (three above the standard), and the current measuring 3,200 ampères. The electro-motive force in the shunt coils was eighty volts. The heaviest current measured 3,400 ampères, the electro-motive force being sixty-eight in the main current and fifty-two in the shunt, the current energy measuring 231,000 watts at the terminals. At the standard speed of rotation, the circuit being broken, the measured electro-motive force was 100 volts.

This remarkable and powerful machine was driven, at the time

of the visit of the writer to the works, by a Corliss engine through a heavy counter-shaft, the engine belt being carried over the belt from the jack-shaft pulley to the machine. This arrangement is an unusual, but perfectly practicable one, and, in this case, worked admirably. It was occasionally necessary to readjust the position of the dynamo, as the belt, which was new and stiff and smooth, stretched more on one side than on the other; but this stretching will soon cease, probably has ceased, and, as the belt becomes more flexible and more perfectly fitted to its pulleys, and as it takes its maximum stretch, it is evident that it will work with perfect accuracy and will be competent to transmit any load that the dynamo can be expected to throw upon it.

The current from the machine to the furnace was conveyed by ropes of fine copper wire, or by conductors made up of several heavy wires. At the furnace, they were connected to the terminals, which latter were of bar copper, apparently about two and one-fourth inches in diameter, armed with four carbons each, the latter of about the same diameter and four feet long. Between these was arranged the conducting material which furnished the incandescent bed in which the operation of reduction was carried on. This process is not, as is very often assumed, by professionals as well as non-professionals, an application of the voltaic arc to the production of high temperatures. Such an application was made by Sir William Siemens and by other experimenters from the time of the discovery of the intense heat of the arc; but it is, in the Cowles process, an application of the incandescence, as distinguished from the arc, system. A connection is established between the carbon terminals, by means of a mass of carbon and other material, which mass is carefully kept continuous and incandescent throughout the whole operation. This is essential both to the success, actual and economical, of the process, and as distinguishing it from the older and wasteful systems of melting. By this system, the intense, the immeasurable heat of the arc is tempered and diffused throughout a large volume of incandescent material, and becomes adjustable and capable of regulation with comparative ease and exactness. Such control is thus secured as to make it convenient and economical in application to the reduction of ores and the melting of alloys and metals. Actual contact carries, everywhere, probably a very large proportion of the current, and the heat is

distributed among numberless little particles of highly heated carbon, which lend each its share to the numberless particles of the compounds to be reduced.

It is probably only by some such application of the electric heat that corundum can be made to surrender its aluminum to form an alloy with copper. It has been stated recently, in the discussion of this process, as described by Dr. Mehner, before the Association for the Advancement of Science in the kingdom of Prussia, at the Berlin meeting of the present year, that this reduction had been accomplished in a furnace heated in the ordinary manner; but it would seem that this must be a mistake; since alumina is one of the most refractory substances known in nature; it is said to be even more so than the materials of our furnaces and of our crucibles. The Messrs. Cowles have subjected it to the highest temperatures that a Dixon crucible would bear, without being able to reduce it or to melt it, in the presence of carbon and copper. Further, it would be probably impossible to successfully maintain a reducing flame, if that were attempted, or to avoid the reoxidization of the metal were its reduction primarily possible. The reducing temperature of the compound is above the temperature of volatilization, also, of the pure metal, and this would make it improbable that its reduction in this way should be successfully performed, far less with commercial success. The volatilized metal would rapidly escape from the Siemens furnace or from any other familiar form of furnace, while no other process than that above described would be capable of forming the volatilized metal in a closed furnace. In the Cowles furnace it is practicable to reduce alumina either with or without the presence of copper or other alloying metal, and one of the first intimations of the production of the working temperatures in that furnace is the appearance of fumes, indicating some volatilization to be produced. As ordinarily conducted, this is not important in amount. Alloys of aluminum have been made in this furnace with nearly all familiar metals, a proof that copper, at least, is not essential to secure the reduction. So far as the writer has been informed, this is the only process by which reduction of this metal with carbon alone can be accomplished. The production of the metal commercially, in this manner, is expected to soon become an accomplished fact. The manufacture of the aluminum alloys has

now for some time been successfully carried on, the cost of the aluminum in the alloy having been reduced to a small fraction of the price for which the metal is sold as made by the older methods. The Messrs. Cowles and Professor Mabery have opened a new and broad field of experiment, and no one can surmise, even, what may come of the infinite range of possibilities so presented.

THE COMPOSITION OF CERTAIN PRODUCTS FROM THE COWLES ELECTRICAL FURNACE.

BY PROF. C. F. MABERY.

[*Read at the Buffalo Meeting of the American Association for the Advancement of Science, August, 1886, and revised for publication in the* JOURNAL, *by the Author.*]

At the meeting of this association last year at Ann Arbor, a paper was presented by the Messrs. Cowles and myself, which gave a description of the electrical furnace and of the products which had then been obtained from it. During the past year, several improvements have been introduced into the construction of the furnace which have increased its efficiency very considerably; and, although, as compared with results that will probably be reached in the application of electricity to smelting purposes, the present development of the process may in the future seem very crude, it has already reached the stage when by actual trials, extending over considerable periods of time, its commercial success can be satisfactorily demonstrated. Those who listened to that paper, or who read it subsequently, will remember that the principle of the furnace is based upon the intense heat that may be produced by the resistance which is encountered when a powerful electric current is passed between electrodes through coarsely pulverized charcoal. In late experiments, it was found by A. H. Cowles that the efficiency of the charcoal could be largely increased, and the rather rapid formation of graphite prevented, to a certain extent, if the charcoal were coated with lime previous to using it. It was also found that the quantity of product formed was increased when the electrodes were allowed to enter the mixture of ore and carbon in an inclined position, at an angle of about 30° from the horizontal plane. A continuous reduction is more

easily effected when the electrodes are capable of being drawn apart so as to gradually expose fresh portions of ore to the action of the current. But perhaps the most important modification for the economy of the process is the adaptation of the furnace by the Messrs. Cowles for the reception of very powerful currents. It consists of a general enlargement of the furnace and the accessory apparatus, including electrodes, conductors and resistance-boxes with certain variations in the detail of its construction. Now the energy from 300 horse-power may be utilized instead of that from thirty horse-power, which was formerly employed. Inasmuch as the resources of the company have been fully occupied during the past year in the development of the commercial features of the process, it may seem that the scientific possibilities have not received due attention. While this criticism may be true in part, I think I shall be able to show that incidentally considerable material of some interest from a scientific standpoint has been collected. I have recently noticed certain statements of opinion concerning the furnace and the process that are not strictly accurate.

In the discussion that followed a paper read by Dr. Mehner, of Berlin, Dr. Martius was inclined to the belief that the metal aluminum was of no greater value for ornamental purposes than zinc, and that its alloys possessed no properties relating to corrosion, strength, etc., that were worthy of mention. These assertions can best be answered by referring to the actual properties of these metals which are established beyond doubt. But the opinion expressed by Dr. Werner Siemens, that so far as practical results are concerned, this electrical furnace is identical with that constructed by his brother, Sir William Siemens, is of more importance. The continuous working of an electrical furnace requires as nearly as possible a constant resistance between the electrodes. Assuming that a dynamo machine was carrying the energy from 300 horse-power and distributing it in an arc a few inches in length, and that suddenly the arc was broken by the introduction of fresh material, the effect upon the dynamo can be imagined. Dr. Siemens thought that the reduction of aluminum depended upon the presence of copper, and he expressed doubts as to whether reduction would result in its absence. Reference was made to the statement that aluminum bronze had been made in a crucible furnace by fusing together copper carbon and corundum. We have tried the

latter experiment at the highest temperature we could produce in a crucible furnace without the slightest reduction of aluminum. Nevertheless, it may be true that traces of aluminum can be introduced into copper by this method. The assertion of Dr. Siemens that aluminum could not be reduced without copper is erroneous. We have repeatedly taken mixtures of metallic aluminum and carbon from the furnace in large quantities. The question by another chemist as to whether any analysis of the products had been made followed a remark by Dr. Martius that they did not need to be informed by Americans concerning aluminum or its alloys.

A product which has attracted considerable attention during the past year is obtained by reducing aluminum in presence of iron. A cast iron is formed containing sometimes as much as ten per cent. of aluminum, and this product is used to facilitate the working of crude iron and to introduce into the various grades a small percentage of aluminum. The slags resulting from this reduction are composed chiefly of calcic aluminate and cast iron. In the reduction of aluminum in the presence of copper, a yellow product is frequently taken from the furnace, which is composed of metallic aluminum to the extent of one-half or three-fourths, the balance being silicon and copper. With a small percentage of calcium it is also formed in the absence of copper and then contains a higher percentage of aluminum and often contains nitrogen. It has a resinous lustre and decomposes water at 100° C. The aluminum slags are composed of reduced metal, calcic aluminate and fused oxide, and since they have always proved to contain about one per cent. of carbon, which is liberated in the gaseous form by hydrochloric acid even in the absence of iron, a carbide of aluminum may also be present. A remarkable effect was observed in a bar of ten per cent. bronze which had been heated for the purpose of forging. It was allowed to become too hot and when struck the entire bar assumed a crystalline condition. Some of the individual crystals were nearly perfect in form, resembling certain forms of the isometric system. A striking analogy between them and certain forms of meteorites, has recently been observed by Mr. O.W. Huntington, of Howard College. In the reduction of silicon, the formation of a greenish-yellow substance is frequently observed, and it has proved by analysis to be a new oxide of silicon—Si O. By fusion with

fluxes it is converted into the dioxide, and hydrofluoric acid acts upon it the same as upon the dioxide.

The ingot of metallic aluminum here shown contains less silicon and iron than the average commercial metal, although no special care was taken to obtain a pure product. It was made by methods which are controlled by patents held by the company, and experiments are in progress which it is expected will lead to results that will cheapen very materially the cost of its production.

CARBOHYDRATE AND FATTY FOODS.

BY N. A. RANDOLPH, M. D., PHILADELPHIA.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *December 14, 1885.*]

Under the general heading of Fats is recognized a certain group of bodies composed of carbon, hydrogen and oxygen, which are capable of saponification and of emulsification, and which are insoluble in water. The true or neutral fats belong to one of three groups; stearine, palmitine and oleine; margarine being usually accounted a combination of the first and third. Chemically, each of these bodies is analogous in composition to any of the neutral salts. In the fats, however, the acid radical is represented by a fatty acid, and the base by glycerin. Thus, stearine may be regarded as the union of stearic acid with glycerin, and palmitine and oleine as respectively a palmitate and an oleate of glycerin. The fatty acid is, however, by far the preponderant portion of the molecule, the glycerin never exceeding from eight to ten per cent. of the substance. The fats named have been mentioned in the order of their solidity at ordinary temperatures, stearine being hard and oleine entirely fluid under usual conditions, while palmitine occupies an intermediate position in regard to density. As foods, these bodies are of extreme importance, though their full value has not been appreciated until a comparatively recent period, because, when taken to the exclusion of other foods, continued nutrition becomes impossible.

We eat fat in a nearly pure state in lard, in oils and in butter. It exists in varying amount in every organic food. Thus we find in

Meats, five to ten per cent.
Eggs, twelve per cent.
Milk, three to four per cent.
Butter, eighty to ninety per cent.
Cheese, from eight to thirty per cent.
Almonds, and nuts in general, fifty-three to sixty-six per cent.
And in all vegetables, from traces to two and three per cent.

Fat is an integral constituent of the higher animals, being entirely absent only in the lowest. It is found not simply in the great reservoirs of the subcutaneous connective tissue, in the omentum, and around the kidneys, but also, finely divided and invisible to the naked eye, in every organ and fluid of the body. Its subdivision is so minute, and its distribution so wide, that especially for muscular tissue it has been well described as being "amalgamated" with the tissue. The chemical composition of fats of different animals is comparatively constant. The mean of eight analyses, including the fat of the ox, sheep, pig, dog, man, cat, horse and butter, revealed an average constitution of $C_{76.5}H_{119}O_{11.6}$, while in the separate analyses these figures differ scarcely one per cent. from one another. Curiously enough, however, the difference in the chemical constitution of the fats of different animals gives to these animals their characteristic odors.

Just as in the body as a whole we find an inverse ratio between its fatty and watery constituents, so in the fatty tissues proper we find a similar relationship. This is strictly correlated with the histogenesis of adipose tissue—*i. e.*, the fat globules are produced in the connective-tissue corpuscle at the expense of the contained watery protoplasm. From figures gained by actual analyses, it may be stated that in the average healthy adult, the fat equals eighteen per cent. of the entire body-weight, or forty-four per cent. of the weight of the dried body.

The extremes in the proportion of fat in the body coincident, apparently, with health, have been most carefully studied in the domestic animals. Thus, in sheep of different degrees of fatness, the following percentage relations in their proximate composition have been found to obtain:

	Per cent. Water.	Per cent. Albumen	Per cent. Fat.	Per cent. Ash.
Thin sheep, ...	57·3	18·4	18·7	3·16
Moderately fat sheep, . . .	50·2	14·0	23·5	3·17
Fat sheep, ...	43·4	12·2	35·6	2·81
Very fat sheep, ...	35·2	10·9	45·8	2·90

In order to appreciate the importance of fats in the economy, we must turn to the phenomena occurring as a result of abstinence from food. In this condition, there is constant disintegration of albumen and fat, the destruction of the latter being twice as great as that of the former. To prevent further loss of fat, either albumen, fat or carbohydrates must be given.

That by its metabolic activity the body can make fat out of other than fatty substances is fully established. A cow subsisting on hay alone accumulates and secretes many times as much fat as she takes in her food. A woman in lactation also secretes much more fat than is ingested. In the process of fattening pigs it has been shown by direct analysis at the end of the experiment that for every 100 parts of fat in the food consumed, 472 parts of fat are stored up in the body. Perhaps the most striking illustration of metabolic fat production is found in the experiments conducted by Hoffmann on a maggot's eggs. The fat percentage in a given weight of these eggs was determined, and a corresponding quantity were allowed to develop in defibrinated blood. When the maggots became mature, it was found that the fat in the eggs from which they were developed, plus the fat in their food, constituted a little less than one-tenth of the fat extracted from their bodies. Here the fat production could be attributed only to separation of albuminoids into other nitrogenous matters and fats.

Pathologically, we frequently see a retrograde metamorphosis of albumen, which constitutes fatty degeneration. Somewhat similar in nature is the post-mortem production of adipocere, in which the proteids of the body have been broken up, possibly by bacterial agency, with the production of the higher fatty acids. The bodies last named unite with earthy and ammoniacal bases to form an insoluble soap, which replaces and assumes the form of the destroyed tissues. As a result of poisoning, especially by

phosphorus, there is also noted a similar production of fat resulting from the decomposition of albumen.

Admitting, now, that fat may be made in the body from albumens, it becomes interesting to note the amount of albumen requisite in the otherwise starving animal to prevent for a time any loss of fat. This quantity is large, and is in inverse ratio to the amount of fat already in the body. In very meagre individuals, it would be impossible to prevent loss of fat under these circumstances, as the requisite amount of albumen would be more than could be digested. By the addition, however, of a small quantity of fat to the albumen, a much smaller quantity of the latter is sufficient to prevent decrease either of the albuminous or of the fatty tissues. As we shall see in studying the history of the proteids of the economy, the most rapid destruction of these compounds takes place not in the formed tissues, as was formerly supposed, but in the circulating fluids. Close chemical studies have shown that when fats are present in company with the circulating albumens they greatly retard the destruction of the latter. In other words, the functionally active cell in any part of the body is bathed in a fluid containing both proteid matter and fat. Only a portion of the force of that active cell is derived from the disintegration of the albuminoid, the remainder being gained from the destruction of the fat. It is especially under muscular activity that the destruction of the fats is most marked, and for this reason they form a most important element in the dietary of the laboring classes. This power of fats to prevent the destruction of the albumens of the body is illustrated by the fact that a moderately fat individual will resist starvation for a longer period than will one of equal muscularity but greater specific gravity. Nevertheless, fat alone is a very insufficient food. It retards the destruction of the albumens, and therefore prolongs, though it cannot sustain life. Thus, Magendie fed two dogs, one on butter, the other on lard, without other food. The first lived sixty-eight days, the other fifty-six. The post-mortem examination showed an accumulation of subcutaneous fat, but general atrophy of the organs. Rats, also, which, in the absence of all food, starve in from three to nine days, will live upon fat for from twenty-six to twenty-nine days.

Under normal conditions, the fats ingested are absorbed with remarkable completeness and in surprising quantity. Thus, in a

dog of nearly eighty pounds weight, to which was given in one day eleven ounces of fat in conjunction with other food, a little less than a drachm of fat could be obtained from the fæces. The maximum limit of fat absorption is not yet established, but it is doubtful whether the amount last mentioned could be absorbed during many successive days. On the contrary, it is highly probable that a degree of saturation of the circulating fluids would be obtained beyond which further absorption would not occur. Experiments instituted by the writer (aided by Dr. Roussel) upon twenty healthy individuals (both infants and adults) with a view of determining the question of the cutaneous absorption of fats, gave the following results:

At the beginning of the experiments, the fæces were, in each case, found to be practically free from fat. After continued inunction of cod liver oil, applied twice daily for a period of two weeks, there was found not only a gain in weight of the individuals (with whom the general dietary had been unchanged), but a notable quantity of fat present in the alvine dejections. This could only be attributed to a kind of saturation of the fluids of the body, which, as a result, prevented further absorption of fat from the intestinal surface, the fat found in the dejections corresponding, therefore, to unabsorbed fat taken in the food. This supposition is strengthened by the observations of Berthé, who showed that pure cod liver oil, given internally, could be taken for a longer time without appearing in the fæces, than could an equal amount of butter or any of the other animal and vegetable fats.

When we remember that the absorption of ingested fats is, in all probability, a result of the purely vital activity of the protoplasm of the intestinal epithelium, it is not difficult to understand the rejection of a needless aliment by this absorbent surface. It is a manifestation of protoplasmic selective power analogous to that exhibited by two dissimilar plants drawing from the same soil each its distinct and special pabulum. Such intestinal selection is illustrated by the behavior of petrolatum (cosmoline, vaseline) in the digestive tract. This substance, while non-saponifiable and chemically distinct from the fats, presents many points of physical resemblance. Prompted by this resemblance, the query arose in my mind, a few months ago, as to the possible absorption of this soft hydrocarbon by the human digestive tract and its subsequent oxi-

dation in the tissues; in other words, whether it could or could not be utilized as a food. On each of eight days I swallowed half an ounce of commercial vaseline, and caused my laboratory assistant to do the same. Digestion was not disturbed in either case, and no noticeable effects ensued. Later, to each of two healthy adults there was given, in the course of forty-eight hours, one ounce of vaseline. Their fæces for three days from the beginning of this experiment were collected, dried, and extracted with petroleum ether. From the extract the vaseline ingested was entirely recovered—evidence of its complete rejection by the intestinal surface. In further experiments upon other individuals, I have found that petrolatum, administered internally, is often sufficient to check rather severe diarrhœas of irritation, apparently acting simply as a mechanical lubricant, which exerts its soothing effect upon the entire irritated surface. It is a curious fact that petrolatum is also efficient in relieving constipation, its action being, of course, that of an unabsorbable diluent of the intestinal contents. The amount requisite to produce the desired result is in this case, however, too large to render the method one of any general usefulness.

In abnormal conditions, such as mechanically obstructed or otherwise impaired biliary or pancreatic secretion, or from diminished activity (from any cause) of the intestinal epithelium, fatty stools are noted. In health, however, fat is found in but minimal amounts in the excreta, although other unabsorbed food elements —bits of muscle fibre, starch, etc.—are readily found. Curiously enough, the presence in the intestinal contents of bran, woody fibre, and the like, materials which impede the proper digestion and absorption of the proteid foods, have little or no effect upon the practically complete absorption of fats. Rubner has shown that the human intestine can absorb large quantities of fat—much larger, indeed, than in the case of the dog just cited; but the length of time during which such absorption could be continued was not determined. In comparison with ham fat, he found butter to be by far the more readily absorbed. Previous accurate observations, already cited, have shown that cod liver oil is absorbed with greater ease and to a greater degree than any of the other fats. The vegetable oils, on the other hand, are the least readily absorbed.

In every sound nutritive schema we find that the fats occupy a

prominent position. It is very significant, in this connection, to note that in the first food of the mammal the fats and albumens are present in practically equal parts. It, of course, goes without saying that a fat which is not entirely fluid at the temperature of the viscera is with difficulty susceptible of emulsification and absorption, and may prove an irritant to weak digestive organs. Although the fats of high melting point contain olein, which is fluid at ordinary temperatures, there is also present sufficient stearin to render a higher temperature requisite for melting the mixture. Thus, the melting point for the fat of mutton is from 41° to 52° C.; for beef, 41° to 50° C.; for pork fat, 42° to 48° C.; whereas the fat of the horse, rabbit and goose is fluid at from 24° to 30° C. These facts suggest the cause of the widespread preference for fats which, in popular phrase, "melt in the mouth."

When digestion and absorption are imperfect, fats may become irritants by undergoing a decomposition which exceeds physiological bounds, with the production of volatile and irritant fatty acids possessing characteristic rancid odors. Somewhat similar decompositions occur at the temperature requisite for frying. This we must regard as one factor in the frequent cases of indigestion of fried foods; and a further reason that the fats, especially when cooked with other foods, are frequently found to be unwholesome is that, in the process of cooking, they so surround and saturate the tissues of the substance with which they are combined that it is rendered nearly inaccessible to the action of the saliva and gastric juice, and at times digestion is in so far delayed that the fried substance does not become entirely freed from this more or less impervious coating of fat until subjected to the action of the pancreatic juice.

Under ordinary circumstances, the fatty acids of the neutral fats are not taken into the economy as such, but in combination with a small amount of glycerin. The fatty acids, however, alone are fully capable of replacing the neutral fats as a food. When administered to a dog in the form of soaps, in conjunction with meat from which all fat had been removed, Munk found that the animal gained in weight in precisely the same way that it would have done had the acid been given in its more usual combination. No nutritive value, strictly speaking, has as yet been determined for the glycerin found in fats, but it is believed that, in the form of

glycero-phosphoric acid, it carries phosphoric acid to the tissues where the latter acid is needed. It is quite well established that the lecithins, which are important constituents of brain tissue, are direct derivatives of glycero-phosphoric acid.

A Carbohydrate is a compound of carbon, hydrogen and oxygen, in which the elements last named are in the proportion requisite for the formation of water. The carbohydrates of the economy and of its foods may be grouped in four classes.

The first includes the glucoses, which possess the formula $C_6H_{12}O_6$. The word glucose may be used as synonymous with grape sugar, dextrose, starch sugar and liver sugar. Glucose is constantly found, in minute quantity, in blood, chyle and muscle. An excess above the small maximum normal to these tissues is immediately rejected and excreted; thus, a solution of glucose injected into a vein at once makes its appearance in the urine, and the glycosuria of diabetes mellitus is attributed to a nervous disturbance of the hepatic function, which permits the entrance into the circulating fluids of a greater amount of this substance than is normal.

In the vegetable kingdom glucose is widespread, being found in the sweet juices of ripe fruits and in the honey of flowers. It is physiologically produced in germinating seeds by the action of the amylolytic ferment therein contained. It is crystallizable, combines feebly with bases, salts, acids and alcohols, and has a reducing action on many metallic oxides. By fermentation with yeast it separates into alcohol and carbonic acid, and in the presence of decomposing albumen it splits into two molecules of lactic acid, which, in alkaline solutions under the same conditions, may be yet further decomposed into butyric and carbonic acids and hydrogen. To this group belong, also, galactose, produced by the action of diluted acid upon sugar of milk, and levulose, an isomeric body, which, however, rotates the ray of polarized light to the left. It is a by-product in the intestinal digestion of starches.

The second division of the carbohydrates contains those of the formula $C_{12}H_{22}O_{11}$, commonly called the saccharoses. They may be regarded as anhydrides of the double glucose molecule. Their physiological type is lactose, or milk sugar, and their type, from a dietetic point of view, is cane or beet sugar. Lactose is capable

of change by direct fermentation into lactic acid, and indirectly by yeast into alcohol, as in the production of koumiss. Cane sugar is, in some degree at least, transformed into glucose before it is absorbed.

The third group includes the carbohydrates of the formula $C_6H_{10}O_5$—*i. e.*, starches, dextrin, cellulose, gums and glycogen. One of the most striking differences between the green plants and all animals lies in the power possessed by the former of manufacturing starch from inorganic substances. The chlorophyl of the green plant, when stimulated by sunlight, can induce the union of six molecules of atmospheric carbon dinoxide with five molecules of water, with the resultant production of one molecule of starch and the liberation of oxygen. No such synthetic power is possessed by any animal, and for the manufacture of a carbohydrate in the animal there is requisite, therefore, either a preexisting carbohydrate or the destruction of an albuminoid. Starch, in its raw state, is entirely insoluble in water. When boiled, the granulose, which constitutes the major portion of the starch grain, and which is contained within an enveloping membrane of cellulose, becomes swollen and ruptures the membrane, with the production of the common starch jelly or paste. Such mechanical hydration of the starch granule is very essential to its digestibility, as the cellulose envelope is but little affected by the saliva. The pancreatic juice, however, is fairly useful in dissolving even raw starch. Starch frequently causes indigestion, when eaten in large quantities, from the following causes:

(1.) Glucose may be formed more quickly than it can be absorbed, and, by its presence, retard the further digestion of the starch.

(2.) Starch, when long retained, is liable to fermentation, with the evolution of butyric acid, thus causing persistent diarrhœas, especially in early childhood.

Much diversity of opinion exists as to the digestion of starches in infancy. I have settled this point to my own satisfaction by the microscopic examination of the fæces of twenty-four starch-fed infants, aged from forty-five days to eighteen months.

The results of this study will be found in the following table.

No.	Age.	Food.	Starch Present.	Remarks.
1	45 days.	Condensed milk and cracker-dust.	None.	
2	2 mos.	"	Traces.	
3	2+ "	"	"	
4	3 "	"	"	Twice examined: no fat before inunction, about 10 per cent. after.
5	3 "	"	"	
6	3 "	"	About ¼ starch.	
7	3 "	"	Traces.	
8	4 "	Corn-starch and milk.	"	
9	4 "	Condensed milk and cracker-dust.	None.	Many broken cellulose envelopes.
10	4+ "	"	Traces.	Evidences of potato surreptitiously given.
11	5 "	"	About ½ starch.	
12	5+ "	"	None.	
13	5+ "	"	"	Many bacteria.
14	6+ "	"	"	10 per cent. fat; had had inunctions.
15	8+ "	Breast and cracker food.	Traces.	
16	10+ "	Condensed milk and cracker-dust.	More than normal.	Many bacteria; evidences of potato surreptitiously given.
17	13— "	"	20 to 30 per cent.	Some glucose present, and indications of dextrin; saliva was found to be inefficient.
18	14— "	"	Traces.	
19	14 "	"	"	
20	14 "	"	10 per cent starch.	Sick.
21	14+ "	"	None.	Except a few large cells containing starch from potato.
22	17— "	"	"	
23	17— "	"	Over ¾ starch.	Syphilitic; saliva was found to be inefficient
24	18 "	"	Traces.	Indications of dextrin.

It should be observed that the word "traces," applied to the presence of starch in the fæces, does not indicate inefficiency of starch digestion. Similar traces of starch are found in the fæces of nearly every healthy adult upon a mixed diet.

It may legitimately be deduced from this study that in *many* cases starch is well digested in early infancy, that the individual variations in this regard are too numerous to permit any sweeping statement, and that the physician may assure himself as to the peculiarities of the case in hand only by a direct examination of the dejecta.

If an infant cannot digest starch, it is self-evident that starch is worse than useless as an ingredient in its food. The converse of this does not obtain; the mere fact that a given infant can digest a certain quantity of a farinaceous material is in itself no proof that such material is a useful ingredient in the dietary of that infant. The ratios existing in human milk between carbohydrate, fat and proteid cannot with safety be greatly altered in an artificial food for early infant life.

Dextrin is prepared by superheating dry starch, and is also found as an intermediate product in the action of dilute acids, and of digestive juices upon starch. It is chemically isomeric with the starch, but presents certain physical differences from this body, being soluble in water, and also much more tenacious as a mucilage. Dextrin is probably absorbed to some degree unchanged from the digestive cavities, inasmuch as there is found in the blood of the portal vein during digestion a substance which gives characteristic reactions, and possesses its properties.

Cellulose is found inseparably associated with the formed tissues of the vegetable kingdom, being one of the chief constituents of the vegetable cell-wall. Its digestibility depends largely upon its age, and upon the extent to which it has been cooked. When young and tender, as in celery, asparagus, and salads, about one-half of its substance is digested, the remainder being of service in giving the proper bulk and consistence to the intestinal contents. This it does, however, at the expense of the complete absorption of the proteid food-stuffs.

The gums possess no permanent nutritive value. Many authors claim that they are entirely unaffected by the digestive processes, but later studies have shown that they are absorbed to the extent of from forty to fifty per cent.

Glycogen, besides being a normal constituent of the human economy, is found in many foods. It is always present in the normal liver in varying amounts, the maximum being obtained in the livers of cattle, where it forms from fourteen to seventeen per cent. of the entire liver substance. It is further found in muscle, in most embryonal tissues, and, according to Pavy, also in the spleen, pancreas, eggs, brain and blood. It is present in considerable amount in the large livers of oysters and other mollusks.

The fourth division contains but one member, viz., inosite. This is a sweetish sugar, isomeric with glucose, but entirely incapable of other fermentation than the sarcolactic. It is variously known as muscle-sugar, bean-sugar and phaseomannite. It exists normally in muscle, where it is decomposed by each muscular contraction, with the resultant production of saracolactic acid. It has also been found in lung, liver, spleen, kidney and brain of oxen. It exists normally in the human kidney and pathologically in the urine. It is found in all the leguminosæ, and also in grape-juice.

We have seen that there are present in the tissues of the body both fats and carbohydrates. The origin of the various carbohydrates is, in greater part at least, directly or indirectly from similar carbohydrates taken as food. Thus, for instance, the glycogen of the liver greatly diminishes in amount in the absence of carbohydrate food stuffs. This is not the case with the fats. Foods containing starch and sugar are well known to be fattening. The explanation of this would at first sight seem to be that fat is made out of these bodies by the metabolic activity of the tissues. This explanation, however, is not correct. The true cause of the increase of body fat upon a mixed diet containing an excess of carbohydrates lies simply in the fact that these bodies become oxidized in the place of the albumens, thereby sparing the latter to fulfil their nutritive functions, and finally to produce fat. The ingested fats aid in the production of fat in the economy, both in this indirect manner and also directly replacing fats already oxidized and disintegrated.

It will be seen from this brief statement that in a mixed diet containing inorganic foods, proteids, fats and carbohydrates, the members of the last two groups are capable of replacing one another to a large extent, for their functions are practically the same, *i. e.*, each sacrifices itself in the oxidation flame of life for the sake of the more valuable proteid tissues and fluids. This is more marked in the case of the carbohydrates, which are able almost entirely to replace the fats in a dietary. Under these circumstances, however, there is found to be a considerable tax upon the metabolic activity of the tissues in manufacturing the fats. In like manner, animals fed exclusively on meat will manufacture from their own tissues the needed carbohydrates in much greater quantity than that in which they exist in the food taken. But here again comes a strain on tissue metabolism, and practically it is found that, other things being equal, it is best to have both the carbohydrates and fats present in the food.

Thus far we have considered similarity in the two groups of organic non-nitrogenous foods. There are, however, certain differences. Thus, a given weight of fat represents one and three-fourths times the nutritive value of the same weight of sugar or starch. Although both of these bodies are heat producers, the fats again have the advantage, and it is for this reason that they assume such

high nutritive importance in cold countries and are consumed by us to a much greater extent in winter than in summer.

The direct bearing which these facts have upon the subject of corpulence is evident. The man who is fat does not of necessity partake too freely of starch and sugar or of oils. He is simply a man who eats too much. His powers of digestion, absorption, and especially of assimilation, are usually far superior to those of his thin neighbor, who may, and often does, eat far more than his obese friend. The plump patient, therefore, must not console himself with his relative temperance in food. He stands perpetually self-convicted as a man who consumes more nutriment than is needed to repair his daily wear and tear. So active are the nutritive processes in his body that he can say with poor Byron, "Everything I eat turns to tallow and sticks to my ribs." He can, of course, reduce his fat by abstinence from carbohydrates and fats, but in so doing he not only violates his nature by turning carnivore, and seriously taxes his emunctories in eliminating an excess of nitrogenous waste, but he needlessly alienates too much tissue-force by the tax and strain of excessive metabolic activity. To permanently and harmlessly reduce his bulk it is necessary simply to very gradually reduce the daily total of his aggregate mixed diet. The popular belief that the ingestion of much fluid is fattening probably arises from observations of the use of fluids other than water.

Given the same degree of obedience on the part of a fat and of a thin patient, it is generally much easier to reduce the former than to fatten the latter. In the first case it is purely a question of abstemiousness. In the second, the simple administration of food in excess of the bodily needs, if unaided by a corresponding stimulation of the assimilating powers, is not infrequently worse than useless. Such a nutritive stimulus may be obtained by the conjoint use of enforced rest, passive exercise by massage and electricity, and a dietary gradually increasing in bulk and variety, the chief factor in which is milk.

For the details of this latter process, I would refer the reader to that gem of medical monographs, Mitchell's *Fat and Blood.*

COEFFICIENT OF EFFLUX FROM AN ORIFICE FURNISHED WITH A SHORT PIPE.

By J. P. Frizell, C. E.

It is well known that the application of a short pipe to a simple orifice in a reservoir results in a material increase of the discharge. Most writers on hydraulics treat this phenomenon as an ultimate fact of science to be determined only by experiment. It is, of course, sufficient for practical purposes, when this case occurs, to

be able to make use of the experimental coefficients of efflux. It is greatly conducive, however, to clearness of knowledge to be able to refer this fact to the well known principles of impact and momentum. Moreover, in hydraulic computations, the same phenomenon presents itself in many forms to which no experimental coefficient is applicable.

The writers* of the splendid article "Hydro-mechanics," in the new *Encyclopædia Britannica* give their view of the rationale of this phenomenon, and express the coefficient of efflux from a short pipe thus:

$$c = \frac{1}{\sqrt{1 + \left(\frac{1}{\mu} - 1\right)^2}}$$

μ being the coefficient of efflux from a simple orifice, c that from the short pipe. If μ be put $= 0{\cdot}615$, this gives $c = 0{\cdot}85$, which is an approximation to the truth, but too large.

My own reflections on the subject lead to a somewhat different formula, which I think it worth while to put in print.

* Professors A. G. Grunhill and W. C. Unwin.

Let v_1 be the velocity with which the water enters the pipe, *i. e.*, the velocity in the smallest section of the contracted vein at the entrance.

v_2 = the velocity of discharge from the pipe.

h = the static head acting on the orifice. This is sometimes measured to the upper edge of the orifice and sometimes to the centre. For this reason tabular coefficients of efflux differ. It must be understood in the same sense with reference to the entrance and exit of the pipe.

μ = the coefficient of efflux from a simple orifice of the form under consideration.

Φ = coefficient of velocity from the same. So that the discharge from a simple orifice, of area A, is $A\,\mu\sqrt{2\,g\,h}$, and the velocity is $\Phi\sqrt{2\,g\,h}$. It is well known that the velocity of issue from a simple orifice falls a little short of that due the static head; a fact which may ordinarily be neglected, but must be taken account of in computations relative to impact and living force.

The water enters the pipe with the velocity v_1 and issues with the velocity v_2. During the passage through the pipe, therefore, an amount of energy, represented by

$$\frac{v_1^2 - v_2^2}{2g},$$

has disappeared. I say energy, although the idea of energy involves the weight of water discharged per second. But as this element does not vary during the computation, it is just as well to regard the energy as represented by the head.

A certain loss of energy occurs in the abrupt change of velocities from v_1 to v_2. According to well known principles, this is represented by

$$\frac{(v_1 - v_2)^2}{2g}$$

This accounts for a part of the energy that has disappeared in passing the pipe, but not all of it. The remainder is represented by

$$\frac{v_1^2 - v_2^2 - (v_1 - v_2)^2}{2g} = \frac{2\,v_2\,(v_1 - v_2)}{2g}.$$

What has become of it? It has been expended in diminishing the atmospheric pressure, which opposes the flow of the water. In other words, the flow of the stream has been increased at the expense of its energy. The water enters the pipe with the velocity that would be imparted to it by the static head

$$h + \frac{2v_2(v_1 - v_2)}{2g};\text{—say } h + H.$$

but

$$\frac{v_1}{\Phi} = \frac{v_2}{\mu} \text{ or } v_1 = \frac{\Phi}{\mu} v_2$$

whence

$$H = 2\left(\frac{\Phi}{\mu} - 1\right)\frac{v_2^2}{2g}.$$

The head required to impart the velocity v_1 is

$$\frac{1}{\Phi^2}\frac{v_1^2}{2g} = \frac{1}{\Phi^2}\left(\frac{\Phi}{\mu}\right)^2\frac{v_2^2}{2g} = h + 2\left(\frac{\Phi}{\mu} - 1\right)\frac{v_2^2}{2g}$$

whence

$$v_2^2 = \frac{2gh}{\left(\frac{1}{\mu}\right)^2 - 2\left(\frac{\Phi}{\mu} - 1\right)} \quad \therefore$$

$$\frac{v_2}{\sqrt{2gh}} = \text{coefficient of efflux} = \frac{1}{\sqrt{\frac{1}{\mu^2} - 2\left(\frac{\Phi}{\mu} - 1\right)}} = c.$$

The value of Φ is, according to Weisbach (*Mechanics*, etc., Coxe, p. 855), 0·975. μ varies slightly with the head. Weisbach takes 0·615 as the working value of μ. Substituting these values in the formula for c, we have $c = 0{\cdot}824$. Weisbach gives 0·815 as the mean experimental value of c, but the values found by different experimenters differ considerably.

ELECTRIFIED BUBBLES.—At the Royal College of Greenwich, soap bubbles were blown of a cylindrical form, and in a vertical position between two concentric platinum rings which served as electrodes. When the bubbles are left to themselves, they exhibit a series of colors in horizontal bands which gradually enlarge and descend; a black band soon appears toward the top and also extends downwards. Electric currents tend to transport the liquid to the negative pole, thus retarding the motion of the bands if the negative electrode is at the top, and accelerating it if the negative electrode is at the bottom.—*Cosmos, Sept. 7, 1885.*

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON IVES'S PROCESS OF ISOCHROMATIC PHOTOGRAPHY.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, November, 1885.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE, of the State of Pennsylvania, to whom was referred, for examination,

FRED E. IVES'S IMPROVEMENTS IN ISOCHROMATIC PHOTOGRAPHY,

Report: That they have carefully considered the process published by Mr. Ives in the *Philadelphia Photographer*, page 365, No. 192, December, 1879, under the title, "On Photographing Colors."

In this paper, attention is called to the fact that colors which, to the eye, seem light, will often photograph dark; while some colors looking dark, photograph light. He claimed at that time to have perfected a process of value in copying oil paintings, and also in making pictures of natural scenery, when a long exposure is possible; and he proceeds to describe the process as follows:

"I place the object to be photographed in a strong light if possible, and use a quick-working objective, directly in front of which is placed a lantern tank, having thin plate glass sides, nearly half an inch apart. Fill the tank with a solution of bichromate of potash, containing one part of bichromate to 1,000 parts of water; focus as usual. Then prepare a plate with 'Newton's emulsion' (I always manufacture it myself, and find it uniform and perfectly reliable) as follows:

"As soon as the emulsion is set, pour upon it a little acoholic solution of chlorophyl (formula below), and float it backwards and forwards for about thirty seconds, after which wash until smooth. Then flow with tea organifier (tea, one-half ounce; water, ten ounces), rinse and expose about two and one-half times as long as required with plain emulsion without tank of yellow.

"Develop with the sal-soda developer (I make this double the strength recommended by Mr. Newton, and dilute where over exposure is suspected). If the bichromate of potash solution is too intense, blue and green will photograph too dark. I have given

the proportions I find perfectly adapted to my tank, lens and chemicals.

"To prepare the chlorophyl, first extract everything soluble in water from myrtle or tea leaves, by treating with a number of changes of hot water; then dry the leaves, and the chlorophyl may be extracted at any time by treating about one ounce of leaves with four ounces of hot alcohol.

"Myrtle leaves yield the most chlorophyl, the solution of which should be a deep pure green color, and will remain good a long while, *if kept in the dark*. It spoils very soon if exposed to a strong light."

Mr. Ives submits to your committee photographs taken from highly-colored pictures, in comparison with photographs made from the same highly-colored pictures by the ordinary wet collodion process. He submits also a chromo of two men playing cards, this is highly colored with plenty of bright yellow and red in contrast with blue. This chromo has been photographed by Mr. F. Gutekunst of this city, using a colored glass before the lens, but not using the chlorophyl as recommended by Mr. Ives.

The result is unsatisfactory; yet, from the well-known skill of the operator, your committee is convinced that it represents the best result obtainable by the ordinary methods of photography, aided by the colored glass. The same chromo photographed by the Ives process, substantially as given in the *Philadelphia Photographer*, in December, 1879, is perfect in detail, and in the gradation of light and shade, as expressed by light or dark pigments, regardless of the actinic effect of the color used. Thus the light yellow is given light in tone, and the darker blue is dark in tone.

Your committee have examined the recorded state of the art at the time of Mr. Ives's publication of his process, and have satisfied themselves that it is the first working, practical process of photographing colors in their relative degree of light and shade as they impress the eye, and that Mr. Ives is entitled to high commendation *for the complete publication, in all its details*, of his process, as well as the high degree of perfection of the results obtained, certainly unequalled up to that time, and unsurpassed, if equalled, up to the present time.

The principle of rendering colors photographically according to

their visual intensity had been proposed before Mr. Ives's publication. Mr. Ives seems to have been the first who made successful application of the principle, in his perfected and published process, which deserves recognition by reason of its novelty, its completeness, and the publication of it without any reservation of information or of rights. In consideration of which, and as a fitting recognition of the benefit bestowed on the art by Mr. Ives, your committee recommend the award of "THE SCOTT LEGACY MEDAL AND PREMIUM" to Mr. FRED. E. IVES, for his chlorophyl process of photographing colors according to their visual intensity.

All of which is respectfully submitted.

COLEMAN SELLERS, *Chm.*,
JOHN SARTAIN,
SAMUEL SARTAIN,
JOS. M. WILSON,
JOHN G. BULLOCK,
W. CURTIS TAYLOR,
FREDK. GRAFF,
CHAS. F. HIMES.

Approved August 4, 1886.

H. R. HEYL, *Chairman.*

APPENDIX.

Notes upon Ives's Process of Isochromatic Photography, comprising the Record of Experiments on the same, conducted by F. E. Ives, in presence of Fredk. Graff, Jos. M. Wilson and John G. Bullock, June 16, 1886.

PROCESS.

Emulsion Used.—Newton's collodio-bromide. Preferably ripe. Fresh is apt to fog. The rapidity of this emulsion is about one-third that of a bath plate in sunlight.

Chlorophyl.—That obtained from blue myrtle or common plantain is preferred. That from the plantain appears to be relatively more sensitive for red than that from myrtle, although the admixture of eosine seems to correct it.

Upon this occasion, Mr. Ives used about equal parts of each, probably one ounce altogether, cut and digested in five ounces Atwood's ninety-five per cent. alcohol, on water bath for about fifteen minutes. Filtered and ready for use; should be allowed to cool.

(*From an Ives Isochromatic Photograph of a Chromo-Lithograph.*)

Subject.—"The Midnight Sun at the North Cape."

IVES PROCESS OF ISOCHROMATIC PHOTOGRAPHY.

(*From an Ordinary Photograph of a Chrome-Lithograph.*)

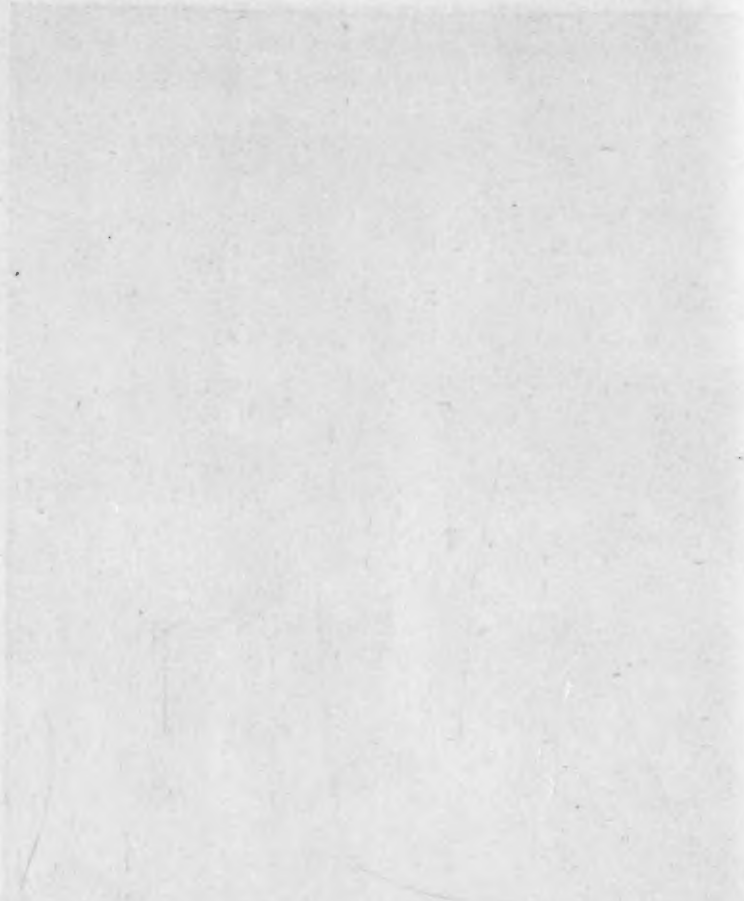
Subject.—" The Midnight Sun at the North Cape."

IVES PROCESS OF ISOCHROMATIC PHOTOGRAPHY.

(*From an Ordinary Photograph of a Chrome-Lithograph.*)

Subject.—" The Midnight Sun at the North Cape."

IVES PROCESS OF ISOCHROMATIC PHOTOGRAPHY.



The plate having been coated with the collodio-bromide emulsion is allowed to set; it is then flowed over five or six times with the alcoholic solution of chlorophyl and immersed in a dish of water, which seems to precipitate the chlorophyl in a very finely divided condition upon the collodion, rendering thereby the plate very sensitive, which it is not, if exposed without the immersion in water.

That chlorophyl remains upon the plate is demonstrated by the fact that after coating a plate so treated with an alcoholic varnish, the last drippings are of a green color.

Fresh myrtle leaves should be used, as the sensitizing properties decrease with age.

Eosine.—About one drachm of a stock solution of eosine, blue shade, thirteen grains to the ounce, ninety-five per cent. alcohol are added to three pints of water, giving a pale cherry red color to the same. The plate is immersed in this solution for about one minute, for the plain eosine plate, and *directly* after flowing with the chlorophyl in the chlorophyl-eosine plate, *without previous washing*, that the two coloring matters may be deposited together.

It does not answer the purpose so well to add the eosine to the chlorophyl solution and then flow the plate.

The yellow sensitiveness in the plain eosine plate may be somewhat increased by a slight action of silver nitrate, *but not where chlorophyl is present.* Free silver salt is destructive to chlorophyl sensitiveness.

An excess of eosine slows a plate. It renders an emulsion sensitive to yellow and green, but not to red, and requires a darker shade of yellow screen for the best results.

Screen.—A solution of picric acid in a small tank, with sides of plate glass: thickness about one-fourth inch between glasses; such was used in the following experiments. A more convenient screen is made by flowing a piece of plate glass with gelatine, staining it with picric acid, and covering with glass, previously flowing with Canada balsam. Such may also be introduced between the combinations of a double lens.

Development.—Soda carb. and soda sulphite with *dry* pyrogallic acid.

The usual stock solutions of pyro., made with sulphurous acid, etc., should not be used. A little bromide is also added. All

forms of these plates develop very quickly. Are likely to fog and may be intensified, but still give good prints. Fumes of H_2S are very destructive. A dark, yellow-green glass, gives the safest light for development of chlorophyl plates.

Subject.—A lithograph containing red, blue, yellow and green in pure colors, and combinations thereof.

FIRST EXPOSURE.

Plate.—Plain collodio-bromide emulsion. Time, one minute; diffused light by window and under skylight. *No color screen.*

Developed quickly, about correct time.

SECOND EXPOSURE.

Plate.—Plain collodio-bromide, *with color screen.* Time, one minute; in sun light reflected from mirror.

Developed. No trace of image. Entirely under exposed.

THIRD EXPOSURE.

Plate.—Chlorophyl. Time, seventy seconds; reflected sun light. Over exposed. Yellow screen used.

FOURTH EXPOSURE.

Plate.—Chlorophyl. Time, forty-five seconds; reflected sun light. Correct exposure. Screen used.

FIFTH EXPOSURE.

Plate.—Eosine. Screen used. Time, forty-five seconds; reflected sun. Correct exposure.

SIXTH EXPOSURE.

Plate—Eosine and chlorophyl. Screen used. Time, *fifteen seconds*, reflected sun light. Exposure correct. Best negative of all.

Comments:—A chlorophyl plate exposed without a yellow screen would be full of detail, but the reds would be too dark and the blues too light.

Mr. Ives claims to be the first to *prove* that the chlorophyl plate produces all colors in their correct relations. The first to prove blue myrtle chlorophyl to be the best of chlorophyls. The first to *combine* eosine and chlorophyl. The only one to give the process to the public.

The relative values of the different sensitizers are demonstrated by the accompanying prints, and those of the spectrum.

Their effect upon the length of exposure rendered necessary, is shown by the list of exposures above given.

In our opinion, Mr. Ives demonstrated, with satisfactory results, all that he claims for his process, which we believe to be an eminently useful one, and one, which, with ordinary care and attention to the instructions, is by no means difficult to manipulate.

[Signed] FREDK. GRAFF,
JOS. M. WILSON,
JOHN G. BULLOCK.

REPORT OF THE JOINT COMMITTEE OF THE FRANKLIN INSTITUTE AND AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION, TO INVESTIGATE THE HAMMER-BLOW, OR MAGNITUDE AND VARIATION OF PRESSURE, OF LOCOMOTIVE DRIVING-WHEELS, ON THE RAILS OF A RAILWAY.

MEMBERS OF THE JOINT COMMITTEE.

FRANKLIN INSTITUTE.

Edward Longstreth, M. E., Philadelphia, Pa.
Coleman Sellers, M. E., Philadelphia, Pa.
T. N. Ely, M. M., Altoona, Pa.
P. H. Dudley, M. E., New York.
T. Shaw, M. E., *Chairman*, Philadelphia, Pa.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.

William Woodcock, M. M., Elizabeth, N. J.
Professor S. W. Robinson, Columbus, O.
Angus Sinclair, M. E., Chicago, Ill.
T. L. Chapman, M. M., Richmond, Va.
Charles Blackwell, M. M., Roanoke, Va.
F. W. Dean, M. E., Scranton, Pa., *Secretary*.

T. Shaw, M. E., *Chairman*.
F. W. Dean, M. E., *Secretary*.

Your committee respectfully report that they have held meetings from time to time, extending over a period of eight months, and have written to and kept informed any absent members, in order

that all could have a correct understanding of the work and give written suggestions where their presence was impracticable.

The committee being composed of professional men, on active duty in different portions of the United States, it was possible to assemble only one-half of its members at any one time.

The work of the committee, though of a seeming simple character, was in a measure problematic, and in a direction that has occasioned much diversity of opinion amongst leading engineers and scientists, many of whom contend that there is no wave force, or so-called hammer-blow, from imperfect balancing, etc., while some of our Master Mechanics maintain that their locomotive driving-wheels are in perfect balance, etc.

It is, however, self-evident upon careful observation, that, to balance any vibrating weight moving in a horizontal plane, by counter-weights in the crank-wheel moving in a vertical plane of rotation, that wherever the balance is made perfect in the horizontal direction, it is out of balance in the crank-wheel in a vertical direction equal to a large portion of the counter-weight employed to correct the horizontal movement. In view of this fact, we find that engines considered most perfectly balanced by counter-weights in the crank-wheel, do occasion great disturbance in a vertical direction (causing a wave force, that may be compared to a hammer-blow), that has a measure of destructiveness upon rails and bridges dependent on weight and velocity of moving parts, and that it is worthy of the most careful examination and test. The forces induced on both sides of the engine, from this cause, are of a complex character, varying greatly, under modifying conditions that occur in practice, and do not submit readily to calculation.

We deem a test of this peculiar action of such importance that we recommend that it be subjected to accurate measurement by means of a special dynamometer that your committee has specially devised, and which we believe is competent for the purpose. We believe also that it will give a correct showing of the complicated and destructive force complained of, and show its exact value, and may perhaps indicate the application of such remedies as may hereafter be found necessary to provide to correct any evident damage in the direction referred to.

A description of the proposed dynamometer is hereto annexed, the cost of which, erected in place exclusive of ground, but cov-

ered by a frame building, is estimated to be $6,000. Your committee having performed their services gratuitously, are not expected, of course, to provide the ways and means to procure the proposed test apparatus.

It has been suggested, however, since the advantage of any test would be with the railroad companies, that possibly these companies would unite in providing the needful apparatus, and that in case it was provided as described, the FRANKLIN INSTITUTE might be intrusted with the custody and possible ownership of the same for the use of all railroad companies. The above estimate includes the expense of Prof. P. H. Dudley's recording apparatus.

For the Committee. { THOMAS SHAW, M. E., *Chairman.*
F. W. DEAN, *Secretary.*

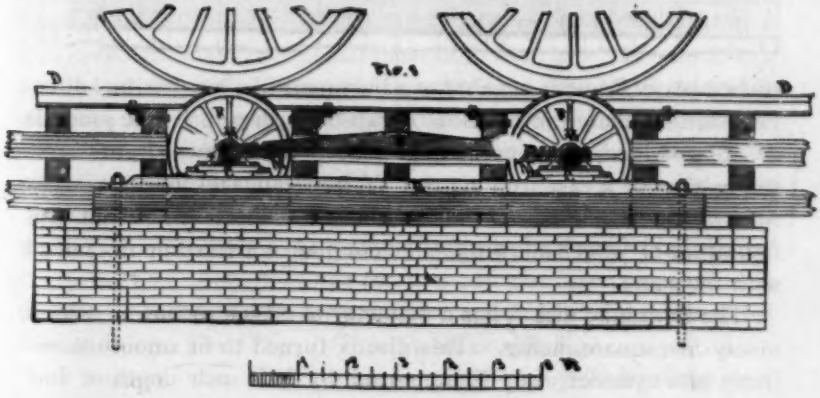
May 31, 1886.

Approved by the Committee on Science and the Arts, September 1, 1886. H. R. HEYL, *Chairman.*

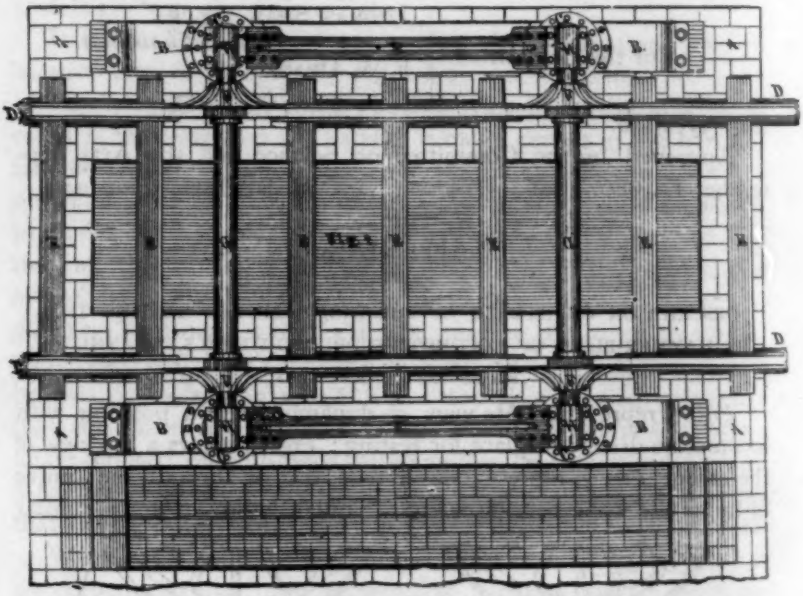
APPENDIX.

DESCRIPTION OF SKETCH OF DYNAMOMETER FOR TESTING THE HAMMER-BLOW OF LOCOMOTIVE DRIVING-WHEELS, ON THE RAILS OF A RAILWAY.

Fig. 1, represents side view of dynamometer in position, with locomotive drivers in place for testing; *Fig. 2*, shows a top view of the same; *Fig. 3*, represents a vertical section through the centre of hydraulic chamber, disc, etc. Similar letters refer to similar



parts, of which *A* represents brick foundation, to which is secured cast iron bed-plate *B*, upon which is supported the dynamometer *C*. Ordinary rails, *D*, are secured to sleepers, *E*, to enable the locomotive to propel itself into position upon the dynamometer wheels, *F*. Said wheels *F*, are solid wheels with little or no elasticity, mounted securely on axles, *G*, running in journals *H*. Said journals form the upper part of disc, *I*, which is free to move vertically in cylinder ring *J*, the said ring *J*, being held in concentric position with the base-plate *K*, by projecting rib *L*. The base-plate *K*, rests upon the planed surface



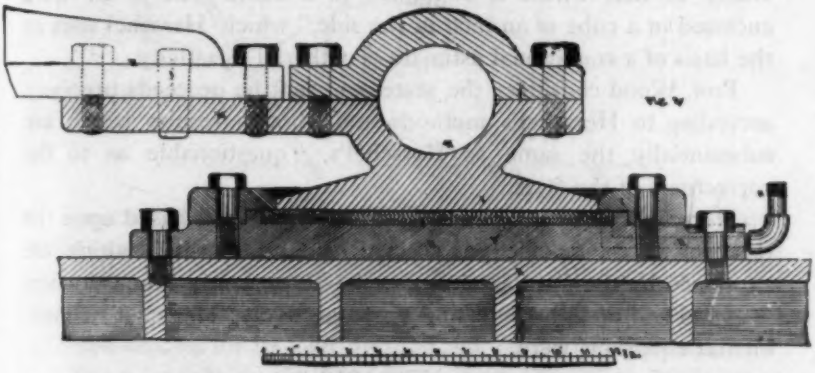
of bed-plate *B*, and is capable of adjustment in a longitudinal direction, and is secured in position by tap bolts shown. The journals *H*, are provided with a projecting rib *M*, pointing inwards, to enable the bolting of a cast iron tie-rod *N*, between said journals. The rails *D*, are fashioned on the ends next to wheels *F*, to suit configurature of wheel, allowing sufficient play, not to come in contact with the same.

The hydraulic disc *I*, has a diameter of eleven inches = area of ninety-five square inches. This disc is turned to fit smoothly and freely into cylinder ring *J*, supported by half inch depth of fluid

(glycerine and water) in chamber *O*. Leakage is prevented at periphery of disc by a thin sheet of pure rubber *P*, which is a diaphragm for bridging the crevice at said periphery, as shown in sketch. This causes the full load to rest solidly upon fluid, with the slightest possible motion and the minimum friction. A passage-way is bored in base *K*, at *R*, for attachment of indicator, or gauge, at *S*. The indicator used in this case must be provided against leakage.

The writer having had occasion to use hydraulic discs of this character for dynamometers for other purposes, finds this method to possess all the accuracy of a pivoted lever in a platform scale; in fact, it works hand in hand with a platform scale.

When a locomotive driver is caused to rest upon the dynamometer, it will give the correct weight of the same, and if said driving-wheel be caused to revolve with any variation in the load occasioned



by imperfect balancing or otherwise, the dynamometer through its indicator, will give correct indications of all such variations, at all speeds where ordinary indicators can be used. The indicator in this case will have the pencil operated from any suitable crank motion on the said driving-wheel, enabling a card to be taken for each half revolution of said wheel, which card will show correctly the pounding force or hammer-blow, fulfilling the purpose your committee have in view.

The locomotive during trial is secured firmly in position, to prevent any longitudinal movement. This can be done by providing heavy bumper timbers on the forward end and clamping engine in position with centres of drivers over centres of the dynamometer wheels.

THOMAS SHAW, M. E.,
Chairman of Joint Committee.

"HYPOTHESIS," OR "ASSUMPTION?"

Professor De Volson Wood's discussion of the properties of the luminiferous æther is so important and valuable, that I am glad to welcome his defence, on p. 226 of the current volume of this JOURNAL, against my charge on p. 129, even though it proceeds upon a mis-interpretation of the real point at issue between us. "The charge of overlooking Herschel's hypothesis," which I did *not* make, is a very different thing from the charge of "overlooking the precaution which Herschel had taken to define his hypothesis," which I *did* make. "The *assumption* that the density of the æther was the same as that of the air at sea-level," which Prof. Wood alleges against Herschel is very different from the "hypothesis that an amount of our ætherial medium equal *in quantity of matter* to that which is contained in a cubic inch of air were enclosed in a cube of an inch in the side," which Herschel uses as the basis of a conditional estimate of ætherial eslasticity.

Prof. Wood considers the statement that he proceeds precisely according to Herschel's methods and obtains results which are substantially the same as Herschel's, "questionable as to the correctness of the facts."

Herschel's reasoning, as well as Prof. Wood's, is based upon the relations of wave-velocity to elasticity and density, which are expressed by the formula $v^2 \propto e \div d$. Representing the velocities of sound and of light by v_1 and v_2, respectively, Herschel's fundamental equations were,

$$v_1 = \sqrt{gh} = 916 \text{ feet.}$$

$$v_2 = 186{,}000 \text{ miles.}$$

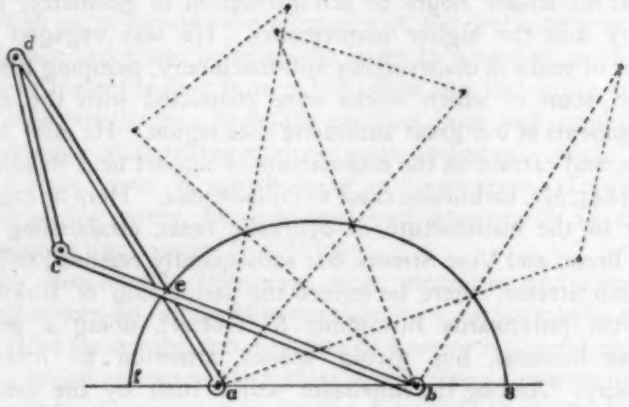
$$e_1 \div d_1 : e_2 \div d_2 :: v_1^2 : v_2^2 :: 1 : 1{,}148{,}000{,}000.$$

Prof. Wood says that "in a pound of the æther there is 100,000,000,000 times the kinetic energy of a pound of air." The discrepancy arises from his inadvertently omitting one cipher and making a rougher approximation than Herschel. The difference of approximation causes a similar slight discrepancy between the two estimates of the ratio when allowance is made for the thermodynamic acceleration of the velocity of sound, Wood's result being 8×10^{11} nearly, while Herschel's is 811,801,000,000; the methods of calculation being the same.

PLINY EARLE CHASE.

A NEW ELLIPSOGRAPH.

There are so many ellipsographs and methods for drafting the ellipse, that a new one can hardly be said to be called for, but the study of the curve is interesting to many from a purely theoretical point of view, and the following device may be new to the subject. It is new to me, both as to its mechanism and its principle.



Four links, *ab*, and its equal, *cd*, *bc*, and its equal, *ad*, are joined together as in the figure, the points *a* and *b* being fixed. As the system is moved about the fixed centres, the intersection of the two crossed links will follow the outline of an ellipse, *fg*, which has the two centres for its focii, and the link *ad* for its major axis.

The figure shows the instrument in rough outline, to illustrate its principle only, but it is easy to see that it would be adjustable for different ellipses if the centres were mounted on sliders, or otherwise made movable on the bars. It would also be a simple matter to attach a double slider that would slide on both the crossed bars and hold a pencil point at their intersection.

Maplewood, Mass., August 29, 1886. GEORGE B. GRANT.

TELEPHONIC TESTS OF ELECTRIC FUSES.—Ducretet rapidly tests the quality of electric fuses of perhaps 1,000,000 ohms resistance, by passing the current from three Lechanché elements through a telephone, the fuse, a coil of fine wire, and circuit-breaker. If the resistance of the fuse be too great, nothing is heard in the telephone when the current is broken or closed; if too small, the telephone makes a deafening noise; if just right, the telephone sounds faintly.—*Comptes Rendus, May 24, 1886.*

HENRY P. M. BIRKINBINE.

The subject of this memorial was born at Reading, Pa., May 21, 1819. He was deprived, by the death of his father, of many educational advantages, and thrown largely upon his own resources. He learned the machinist's trade, and, while still at the bench, devoted his leisure hours to self-instruction in geometry, trigonometry and the higher mathematics. He was engaged for a number of years in constructing mill-machinery, pumping machinery, etc., some of which works were connected with the earlier developments of our great anthracite coal region. He also leased a forge, and carried on the manufacture of augurs near Reading.

In 1845, Mr. Birkinbine came to Philadelphia. Here he engaged at first in the manufacture of hydraulic rams, establishing himself at Broad and Vine Streets, but subsequently removed to Front and Arch Streets, where he formed the partnership of Birkinbine & Martin (afterwards Birkinbine & Trotter), doing a general machine business, but giving special attention to hydraulic machinery. Among the important works built by the firm, for its own account, or under contract, may be named the Gas-works and Water-works for Germantown (erecting the first stand-pipe in America); the West Philadelphia Water-works—the Bull Cornish Engines being designed and erected in their shops; the pumps and Water-works of York, Pa., and other towns; and considerable work for exportation, chiefly to the West Indies.

After the dissolution of the firm above named, Mr. Birkinbine, for some years, continued the same business, and, for himself and others, constructed numerous public water- and gas-works, and heating and ventilating apparatus for hospitals and public institutions.

Mr. Birkinbine was chosen Chief Engineer of the Philadelphia Water Department in 1857, and served in this office from 1858 to 1861, and again from 1864 to 1866 inclusive. While occupying this position, he built the new wheel house and pumps at Fairmount, repaired the dam at Fairmount, made exhaustive tests of turbine wheels (in 1861), constructed the Roxborough reservoir and pumping works, raised the Corinthian Avenue reservoir to equalize the water storage, laid large feeding mains and built the

water-tower and arch at Fairmount. During the construction of the latter, he received injuries from which he never fully recovered, and which undoubtedly shortened his life.

During his administration as Chief Engineer of the Water Department, Mr. Birkinbine investigated the subject of the future water supply of Philadelphia, and prosecuted preliminary surveys as far as the funds appropriated would permit. His conclusions are embodied in a special report to the City Councils, dated 1865, in which he recommended the utilization of the drainage area of the Perkiomen Creek and bringing the water by aqueduct to the city.

After his retirement from public office, Mr. Birkinbine engaged in private practice as a hydraulic engineer, and was employed as consulting or constructing engineer upon a number of works, public and private, some of which were of importance. During this period of his career, he was employed temporarily as General Manager of the Camden Iron Works.

Mr. Birkinbine's inventions were numerous, and comprised, among others, an improved hydraulic ram; a water-cushion, double-beat valve for pumps, and a system of fire-protection for cities and towns, which embraced the feature of permitting a change from the reservoir to direct pressure, by the employment of valves moved by air compressed by the static pressure of the water supply. This system is at present in use in a number of cities and towns.

Mr. Birkinbine's published works were chiefly in the form of reports or papers. The more important of these were his reports as the Chief Engineer of the Philadelphia Water Department, which form nine annual volumes; his history of the Philadelphia Water-Works, and his reports on the water supply of Harrisburg, Reading, Allentown, Lebanon, Lancaster, Bethlehem and other cities. Mr. Birkinbine had made himself master of the subject of water rights, and his services were frequently called in requisition in important legal cases—among the notable cases in which he was engaged was that of the Schuylkill Navigation Company *vs.* the City of Philadelphia.

Mr. Birkinbine became a member of the FRANKLIN INSTITUTE in March, 1845, and sometime later became a life member; and for many years took an active share in its work. He was elected to the Board of Managers in 1851, and served in that capacity from 1851 to 1856.

The following is a list of his contributions to the JOURNAL OF THE FRANKLIN INSTITUTE, viz:

Birkinbine, H. P. M., and Trotter.—"West Philadelphia Water Works Stand-Pipe," lix, 210.

Birkinbine, H. P. M., "Economy of Using Steam Expansively," lxxiii, 34.

"Pumping Engines," lxxxvii, 323; lxxxviii, 109.

"Stand-Pipe for Bloomington, Ill.," c, 234.

"Rainfall in the Schuylkill River Basin," ci, 185.

"The Schuylkill River," ci, 321.

"Relative Cost of Steam and Water-Power," cv, 47.

"The Future Water Supply of Philadelphia," cv, 305; cvi, 38; cviii, 297.

Personally, Mr. Birkinbine was a man of positive convictions, thoroughly in earnest in everything he advocated and undertook. He leaves behind him the record of a busy, an active and useful life. At the time of his death, which occurred on the twenty-first of April, 1886, he had almost completed his sixty-seventh year.

W. BARNET LE VAN, *Chm.* WASHINGTON JONES,
JOHN H. COOPER, C. CHABOT.

EMILE FRANCOIS LOISEAU.

Our late fellow-member, Emile François Loiseau, died at Brussels, on the thirtieth day of April, 1886, in the fifty-fifth year of his age. He was a native of Belgium, in which country he received an education to prepare him for one of the learned professions; but, becoming dissatisfied with the sedentary pursuit selected for him, he withdrew from college and commenced a business life of congenial and active character. He served for eight years in the French army, participating in the Crimean campaign. He was then upon the editorial staff of a Parisian journal, and subsequently became superintendent of an industrial works in Belgium. Whilst in that position his liking for mechanical pursuits so developed, as to determine his future life-work. It was during this period that his attention was drawn towards the immense deposits of coal waste at the Belgium mines, which were constantly increasing, as

the processes then in vogue were imperfect and unequal to the requirements. To the problem of utilizing this waste material, Mr. Loiseau devoted his earnest and intelligent efforts, and devised a process, with the necessary machines, which would more rapidly put it into convenient sized lumps for domestic or steam users' consumption. As the European field was partially occupied, he concluded to introduce his method into the United States, and began operations near Nashville, Tenn., but soon removed thence to Pennsylvania, which promised a wider field and better market, and for the reason that his plans had won the favorable regard of several extensive coal operators in the anthracite region. At Mauch Chunk, the first experimental machinery was built, and gave such satisfactory results, that a company was formed for the purpose of utilizing the great mounds of coal waste to be found in Pennsylvania. About this time (see this JOURNAL, January, 1874,) Mr. Loiseau read before the FRANKLIN INSTITUTE a highly interesting paper upon the manufacture of "Artificial Fuel," in which he described the processes and machines in use up to that date. In furtherance of the intentions of his company, Mr. Loiseau designed, and had built at Mauch Chunk, a machine capable of making 100 tons of compressed fuel per day in lumps of the shape and size of hen's eggs. In this machine he embodied what he considered to be good in existing machines, and supplemented it with some important details of his own devising. When completed, it was erected at Port Richmond, near the coal wharves of the Reading Railroad Company, at which point it was expected coal dust could be had in quantities. After the delays and mishaps inseparable from new enterprises, and which were borne by Mr. Loiseau with indomitable courage, the apparatus, with such modifications as later experiences had taught, was got into such excellent working condition as to yield about eighty tons per day of ten hours of agglomerated anthracite dust of dense, non-friable and weather-proof qualities, which met with a ready sale at a price but little below that of natural lump coal. Unfortunately at this juncture, the buildings took fire and were totally consumed. Previous to this disaster, when the success of his methods had been assured and patented in the European countries, Mr. Loiseau had entertained proposals made to him, by some important coal companies in France and Belgium, to erect his machines at their mines, and

as the destruction of the works at Port Richmond, and the inability to procure coal dust at that locality in quantities and at desirable prices, influenced his company against rebuilding. Mr. Loiseau then determined to accept a proposition made to him by a Belgian coal mining company at Ham-sur-Sambre, and had built in Philadelphia and shipped to Belgium, the patented parts of a machine capable of compressing twenty tons of dust, accompanying them to superintend their erection and operation, and to demonstrate the practicability of his process. It reached the mines, but, unfortunately, was not put up, as the strike of the Belgium miners soon after took place; hastened, perhaps, by the anticipated loss of employment from the use of such a labor-saving machine. The more valuable parts taken from the United States were hidden under coal dust to preserve them from the fury of the mobs. This derangement of his plans, with threats of violence directed against his person, added to general ill health, brought upon him an acute attack of sickness, which terminated his life at the time when his many years of persevering efforts seemed on the verge of securing for him the substantial reward they merited.

WASHINGTON JONES, *Chm.*, W. BARNET LE VAN,
C. M CRESSON, M. D., WM. H. WAHL.

JOAQUIM BISHOP.

JOAQUIM BISHOP died on the 8th of August, 1886, in the eighty-third year of his age.

Mr. Bishop was a pioneer in the manufacture of platinum in the United States. Born of English parents, in Portugal, in 1804, he came with them to Baltimore in 1810, leaving Portugal, where his father was engaged as Director of a department of Government work, on account of the invasion of the peninsula by the armies of Napoleon.

After a residence of one year in Baltimore, the family removed to Philadelphia.

At the age of twenty-two, Mr. Bishop entered as an apprentice to the jewelry business, but soon after changed his vocation to that of a finisher in a brass foundry.

In 1832, he engaged with Prof. Robert Hare, as an assistant, at the University of Pennsylvania. While in this position, his attention was attracted by the experiments of Prof. Hare with the

oxyhydrogen blow-pipe. The melting of platinum was done by Prof. Hare, on a limited scale, for commercial purposes.

In 1839, Mr. Bishop commenced business as a manufacturer of philosophical instruments, on Laurel Street, removing, in 1851, to Pear Street, adding to his business the melting and working of platinum. This department increased to an extent which induced him to devote his attention entirely to it. Removing, in 1858, to Radnor, in Delaware County, he again, in 1865, changed his location to Sugartown, in Chester County. At the latter place, he erected a commodious laboratory and work-shop.

At the exhibition of the FRANKLIN INSTITUTE, in 1845, he received a premium for his exhibit of platinum; and at the Centennial Exhibition of 1876, he was the only exhibitor of platinum work done in the United States, for which he received a medal and diploma. C. B.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, September 15, 1886.*]

HALL OF THE INSTITUTE, September 15, 1886.

CHAS. H. BANES, President, in the Chair.

Present—146 members and twenty-one visitors.

The election to membership of twelve persons was reported.

The special committees charged with the duty of preparing memorials of EMILE FRANÇOIS LOISEAU and HENRY P. M. BIRKINBINE, lately deceased members, presented reports, which were accepted and referred to the Committee on Publications.

The Chairman of the Committee on Science and the Arts reported the recommendation of the committee for the award of the ELLIOT CRESSON MEDAL to EUGENE H. and ALBERT H. COWLES, for their "invention of a new process in the metallurgical arts for the reduction of refractory substances;" and of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to the same inventors, for their "Electric Smelting Furnace."

The recommendations were severally approved, and the Secretary was directed to take the usual measures to carry them into effect.

A communication was presented from PAUL LA COUR, of Copenhagen, Denmark, touching the recent award to PATRICK B. DELANEY, of New York, of the ELLIOT CRESSON MEDAL, for his "Improvements in Multiplex Telegraphy." Action thereon was deferred.

Mr. S. LLOYD WIEGAND read a brief communication, descriptive of "Schaefer's Compound for Improving the Quality of Steel," and exhibited the operation of the process and specimens. The compound is a mixture of linseed oil, resin, glycerine and carbon.

The Secretary's report included remarks on recent progress in electric smelting; a description of the Brush "Colossus," a dynamo-electric machine of great power, built for the Cowles Electric Smelting and Aluminum Company, for their electric smelting works, at Lockport, N. Y., together with the record of the trial tests of the same; and on the recent earthquake on the Atlantic border of the United States. In this connection, there were shown numerous illustrations, exhibiting the ruins of the city of Charleston.

PROF. E. J. HOUSTON offered some remarks on earthquake phenomena in general.

The Secretary exhibited and described the "Twin-Sheave System for Electric Cables and Wires," the invention of Messrs. Fondersmith & Wilson, of Philadelphia, which is claimed to be adapted for the reception and carrying of cables and wires underground, on the surface, against walls, through tunnels, or elsewhere, where facility is wanted for readily drawing cables in or out.

The meeting then proceeded to the final consideration of some proposed amendments to the By-laws, and was thereupon adjourned.

WM. H. WAHL, *Secretary.*

BOOK NOTICES.

RECENT PROGRESS IN CHEMISTRY. An Address prepared at the Request of the New York Academy of Sciences, and read March 15, 1886. By H. Carrington Bolton, Ph. D., Professor of Chemistry, Trinity College, Hartford.

This most interesting and valuable résumé of the world's advancement in one of the most fruitful as well as most difficult lines of research, is conceived in the spirit of Hofmann's *Introduction to Modern Chemistry*, of over twenty years ago. It is a scholarly though plain statement of the progress of chemistry as seen to-day by the eye of one of the masters of the science.

Professor Bolton has long since won the admiration and received the thanks of the chemical world for his pains-taking labors in collecting the widely scattered data in chemical literature bearing upon special branches of the subject. In this treatise, he gives a general view over the whole field, and in spite of his scientific caution and studious avoidance of the defect of merging the horizon of cloud with the horizon of earth, he does not conceal the commendable and cheery exultation of a worker in viewing the present state of the structure he has helped to rear.

This essay can be heartily recommended to the general reader as well as to the professional chemist. Each will be gratified and astonished at the census; indeed, the latter is likely to experience these emotions more than the former unless, which is unlikely, he shall have taken considerable time from his own investigations to obtain the information which Professor Bolton here gives. The discourse is divided into twenty-two paragraphs, and is followed by seventy-eight citations of authority for its various statements. Nos. 1 and 2, deal with the artificial difficulties of chemistry and the large number of workers in that field; No. 3, glances at the recent list of supposed new elements; No. 4, at the new physical apparatus for chemical discovery; No. 5,

shows the errors which accompany a too blind acceptance of Prout's law, and reclaims for Professor Cooke, of Harvard, the priority of announcing the variations in the amount of chemical energy expressed by an atomic weight; 6 and 7, treat the discovery by Mendelejeff and others, of the periodic law of elements and the prophecies that have been made and verified, and Dr. Carnelley's hypothesis that all elements are compounds of carbon and æther; 8, 9 and 10, present an interesting survey of the modern views of catalytic action, or that in which a third body causes chemical changes in which it does not participate, together with examples of the indifference to each other of various bodies at low temperatures, which are types of violent affinity at ordinary temperatures; 11, 12, 13 and 14, are taken up with a summary of the work done on the interesting border line between chemistry and physics; 15, apprises us of the recent enlargement of the field of manufactures in inorganic, and 16 and 17, in organic chemistry; 18 and 19, urge the claims of diagrammatic chemistry, and the author boldly deals with open and closed chains of molecules, with hexagons, etc., as if there were no chemical old women in the world to be shocked; 20, tells us what progress has been made in imitating plant products in the laboratory, and 21, frankly avows the standstill in animal chemistry. In the concluding paragraph, these words occur: "The tendency of modern research in chemistry is to magnify the atomic theory; the rapid accumulation of facts, the ever increasing ingenious hypotheses, the most searching examinations of co-ordinate laws, all tend to strengthen the Daltonian adaptation of the philosophic Greeks. Here and there a voice is raised against the slavish worship of picturesque formulæ; but against the molecular theory underlying the symbolic system so depicted, few earnest arguments are advanced," etc. What will those eminent gentlemen, who still retain belief in the continuity of matter and the futility of all attemps to specify its units, say to this?

THE ECONOMICAL ASPECTS OF AGRICULTURAL CHEMISTRY. An Address before the American Association for the Advancement of Science at the Buffalo Meeting, August, 1886. By Harvey W. Wiley, Vice-President Section "C." Cambridge: John Wilson & Son, 1886.

In this pamphlet of thirty-seven pages, the Chairman of Section "C" gives an extended view of the field of agricultural chemistry at present covered by active workers. One can see from this panorama the same energetic research, the same intelligent war upon what seem at first insuperable difficulties, but which are sure to be overcome in the end; and even (by reading between the lines) the same jealousies and reclamations which make up the characteristic scenery of vigorous inductive science. The former and worthier motives may be compared to the "nitrifying organisms," which are so frequently alluded to in the address; and the envy and all uncharitableness which appear in the disputes of eminent men over the question as to who first or most discovered a fact since proved to be important, to the "denitrifying little corpuscles," which co-exist with their opposites in the same plant and serve the general purpose of Nature by undoing or trying to undo all that the latter have accomplished. It is not one of the least merits of Prof. Wiley's address that

it suggests to the reflective mind, that even these very disagreeable creatures (human), which seem to hang about the flanks of the army of investigators like jackals, and to prey on the offal and stragglers, may be shown by analogy to have their uses. The address is divided into a preliminary part, which deals with the statistics of the weights of the products of the soil of the United States each year, and of the ashes of these products; and of the weights of the potash and phosphoric acid in these ashes per year. The next and most important part of the address discusses the part which nitrogen plays in the growth of plants. This leads to the question of how the plants absorb nitrogen and what is the best means of preventing useless waste of this necessary constituent of the proteids and how to increase the supply of nitrogen to the soil. The researches of Pasteur, Schlösing, Müntz, Warrington, Berthelot, Dehérain and Joulie, as well as the observations of Pichard, of Gayon and Dupetit and of Maquenne are ably treated and von Tiegham's "Butyric Ferment" is referred to as probably the "Bacillus amylobcater." Some of the subjects which are taken up under the general head of the "Nitrogenous Food of Plants" are: (1.) Organic nitrogen; (2.) ammonia; (3.) the oxidation of nitrogen due to combustion; (4.) nitrogen oxidized by electrical discharges; (5.) fixation of free nitrogen in soils; (6.) fixation of free nitrogen by the plant; (7.) mineral nitrates; and a short conclusion on the "Future Food Supply." The last paragraphs of this latter portion will serve as an apology for whatever reflections the writer of this has just indulged. "It is probable that all life, vegetable and animal, had its origin in the boreal circumpolar regions. Life has already been pushed half-way to the equator, and slowly but surely the armies of ice advance their lines. The march of the human race is a forced march, even if it be no more than a millimetre in a millenium. Some time in the remote future the last man will reach the equator. *There with the mocking disc of the sun in the zenith, denying him warmth, flat-headed and pinched as to every feature, he will gulp his last mite of albuminoids in his oat-meal, and close his struggle with an indurate hospitality.*"

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1885.

ABSTRACTS OF REPORTS OF THE JUDGES.

(Continued from page 239.)

PULSOMETER STEAM PUMP COMPANY, NEW YORK.

The New Pulsometer Steam Pump.—This is a double-acting, two-cylinder, lifting and force pump, in which steam acts directly upon the water without the intervention of any mechanical appliances. Steam is admitted into each cylinder through a ball valve at the top, which operates automatically, and closes the passage into one cylinder while it opens it into the other.

Condensation occurs when the valve is closed and water is drawn in by the partial vacuum thereby produced, and at the same time the water in the other cylinder is forced out by the live steam.

When a certain amount of water is forced out of this cylinder, condensation takes place so rapidly that the ball valve rolls over, seals the chamber, and admits live steam into the other cylinder, which has just been filled with water.

From the construction of the pump, it appears that condensation must take place with increasing rapidity from the moment steam is admitted until it is cut off by the rolling over of the valve.

In this valve the ports are close together, and the ball rolls easily from one to the other, thus controlling the admission of steam in a very quick and effective manner.

The water valves are of two kinds, one a plain check with rubber facing, adapted to clean water, and the other a hard rubber ball valve, recommended for sand and gravel.

The feature to which special attention was directed was the new style air valve, used to admit a slight amount of air at each stroke in order to keep the steam and water from actual contact.

The adjusting nut for regulating the admission of air in this valve is held in position by a latch, which catches into notches cut in the nut instead of by a jam nut, as formerly. The change may be readily conceived to be an improvement, but further than this the committee were unable to discover any points of novelty.

The pump is one which recommends itself for its cheapness, simplicity and durability, but without the evidence of a practical test, the committee are unwilling to admit its claim for economy in steam, and make no recommendation.

RAND & HARMER, PHILADELPHIA.

The Siddall Hose-Coupling.—This is an ingenious device for the purpose of quickly coupling hose, and is similar in principle to the old wire stopple for soda water bottles. Its durability will not compare with that of the screw coupling, as the rough usage all hose is liable to get will break off the small pins or lugs to which the lock lever is attached. If this should occur, or the rubber washer slip off, the device is rendered useless.

D. WALKER WEBSTER, LANCASTER, PA.

Water Motor.—This motor consists of an overshot water-wheel on an horizontal axis. The water issues from the inlet passage in one or more small jets, and in a tangential direction to the path of motion, and at a slight angle to the back of the buckets The wheel is driven by the impact of the jets of water against the buckets, and it is doubtful whether much additional power is obtained from the weight of any water remaining in the buckets during the position of a revolution. The centrifugal force throws the spent water to the periphery of the casing, whence it finds its exit at an opening in the bottom. Guards are placed on the inside of the casing over the axle, in order to prevent any drip getting into the bearings. We were unable to make any tests, or to get any reliable data or information as to the efficiency of the motor. The ajutages and buckets are well shaped, and placed in proper relation to each other, and the bearings, needing no packing to keep the water from them, can run with a minimum of friction and can easily be kept in good condition.

WILBRAHAM BROTHERS, PHILADELPHIA.

Rotary Pump, Pressure Blower and Gas Exhauster.—These machines, though differing from each other in some of the details of construction, all depend upon the principle of the well-known Baker blower.

The external housing of each of these machines is a semi-cylindrical iron casting, having flanged outlets on opposite sides for suction and delivery. Concentric with this housing, and revolving freely inside is a hollow drum, carrying two vanes diametrically opposite, which act as the rotating piston. Below are two other drums with openings on one side that permit the passage of the rotating piston, and they are so geared to main drum-shaft as to present their openings to the piston as it advances, revolve with it, and close the passages immediately after, the combination of these two drums always acting to prevent the return of the fluid to the suction pipe.

In the pressure blower and gas exhauster, the journals of the rotary piston and drums are in ends of casing, but in the rotary pump, the shafts pass through stuffing-boxes and bear in pedestals firmly connected to base-plate of the machine; the stuffing-boxes

are so designed that the packing bears against filletted shoulders on the shafts, in order to increase as little as possible the resistance to rotation.

The gas exhauster is used when a very steady flow of gas at low pressure is required, and is usually connected directly to driving engine, and governs speed of rotation by supply of gas. In this machine, the gear wheels for driving the drums are covered with a gas-tight housing. Oil-cups are placed outside, and in such position as to give sufficient head to the lubricant to flow into bearings against internal pressure.

It is the opinion of the committee that the efficiency of these machines should be high, because all the work of forcing the fluid is done by direct pressure, and the motion of the fluid in passing through the pumps is continuous, and with but slight change of direction; and that, as there are no valves, ports or narrow passages through which the fluid has to be drawn, the loss of head due to friction should be small.

The only apparent losses are due to the rotation of the valves, to the friction of the shafts in stuffing-boxes and bearings, and to the leak that might occur around ends and sides of rotating piston.

In regard to wear of working parts, it may be said that, although these machines require to be constructed with great care, and depend, in a great measure, for their effective working upon the accurate setting and fitting of drums and drum-shafts, yet they are so designed that the wear on these parts should be small if proper care be expended upon them.

In consideration of the above, the committee would respectfully recommend the award of— (*A Silver Medal.*)

GROUP 11*f*.—STEAM BOILERS AND FURNACES.

Judges:—Arthur L. Church, *Chm.;* Griffith M. Eldridge, George A. Vaillant.

The judges, to whom was referred class 11*f*, steam boilers and furnaces, respectfully report as follows:

The seventy-five horse-power boiler from the Baldwin Locomotive Works, in boiler house, used at and remaining from the Electrical Exhibition of 1884, rendered efficient service throughout the Exhibition. (*Not entered for competition.*)

Two 100 horse-power Harrison sectional safety screw boilers, in

boiler house, fully sustained their well-established reputation in making steam supply for general use of the Exhibition.

(*Not entered for competition.*)

CHALMERS–SPENCE COMPANY, PHILADELPHIA.

Asbestos Manufactures.—This exhibit embraces fabrics of pure asbestos, notably among them curtains for protecting the auditoriums of theatres from injury by accidental fire upon the stage. Also removable steam-pipe and boiler coverings for retarding loss of heat by radiation; both of these inventions are of demonstrated excellence and reliability. The committee recommend them the award of— (*A Silver Medal.*)

GLENMORE IRON FOUNDRY, PHILADELPHIA.

Sectional Furnace Grates, and Supports therefor.—For the economical, durable and convenient properties shown in this grate, the committee recommend the award of— (*A Bronze Medal.*)

C. H. HOLT, PHILADELPHIA.

Fuel Economizer for Utilizing Heat of Products of Combustion in the Flue leading from Boilers to Chimney.—This invention is of the general type of the well-known Green economizer; is of a most durable and substantial construction, and is provided with means for effecting circulation of the water in its tubes.

For excellence of design and workmanship, the committee recommend the award of— (*A Bronze Medal.*)

J. E. LONERGAN & CO., PHILADELPHIA.

Lynde's Safety Valve, Water-feeding Regulator, and High- and Low-Water Alarm for Steam Boilers.—For efficient and reliable action and safety, a diploma of— (*Honorable Mention.*)

E. S. MORSE, PHILADELPHIA.

Feed-Water Heater.—This consists of a horizontal cylinder containing feed-water, and provided with proper inlets, outlets and openings for cleansing. Through this cylinder a series of parallel small tubes pass horizontally, conveying exhaust steam, which imparts its heat to the water and causing precipitation of some of the impurities of the water. For good construction, the committee recommend a diploma of— (*Honorable Mention.*)

WHETSTONE & GRAU, PHILADELPHIA.

J. P. Grau's Feed-Water Heater and Purifier.—For efficiency and

simplicity in heating feed-water and precipitating impurities therein, and thus protecting steam boilers from injury—

(*A Silver Medal.*)

T. E. SUTNER, PHILADELPHIA.

Cooke's Damper Regulator.—This is a diaphragm regulator of the well-known Clark type, protected by a water column from the temperature of the steam, and is operated by steam pressure admitted and relieved by an automatic valve, easily adjustable to any desired steam pressure. For prompt and reliable working in controlling high steam pressures, we recommend the award of—

(*A Bronze Medal.*)

H. B. SMITH MACHINE COMPANY, PHILADELPHIA.

Kellam's Steam Damper Regulator.—This invention is operated by steam pressure applied directly to a piston working with a minimum of friction in a vertical cylinder; is readily adjusted, and promptly and efficiently controls the steam pressure of boilers working within their proper capacity. It is also applicable to operate valves for controlling reduced steam pressure from a high pressure supply.

For good design and construction, and prompt and reliable working, the committee recommend— (*A Bronze Medal.*)

THOS. Y. DE NORMANDIE, PHILADELPHIA.

Geisler's Smoke Consumer.—This invention was applied to the Baldwin seventy-five horse-power boiler, which was operating economically without it, and did not offer such opportunities to demonstrate a saving of fuel as many of the boilers to which it might be applied.

(See report of Test Committee.)

GEORGE KINGSLEY'S BOILER.

(See report of Test Committee.)

WM. M'ILVAIN'S SONS & CO., PITTSBURGH, PA.

Specimens of Boiler Plate.—Showing the excellent ductility of metal, proved by most difficult flanging, without developing any flaws or defects.

For excellent quality of material— (*A Bronze Medal.*)

APPENDIX TO REPORT OF JUDGES, 11*f*.

TEST OF THE KINGSLEY BOILER.

PHILADELPHIA, December 7, 1885.

GEORGE A. VAILLANT, ESQ., *Chairman pro tem Section 11f:*

DEAR SIR:—The sub-committee appointed to test the Kingsley boiler respectfully presents the following report:

On November 6, 1885, a test was made for evaporative efficiency, and on November 7th a test for capacity.

The apparatus used during the test was obtained by Mr. S. Lloyd Wiegand. The scales were standard Fairbank's platform scales, the thermometers by A. Kuchler & Son. The steam-gauge, thermometers, scales, etc., were tested by Mr. W. Barnet Le Van, and corrections made for inaccuracies.

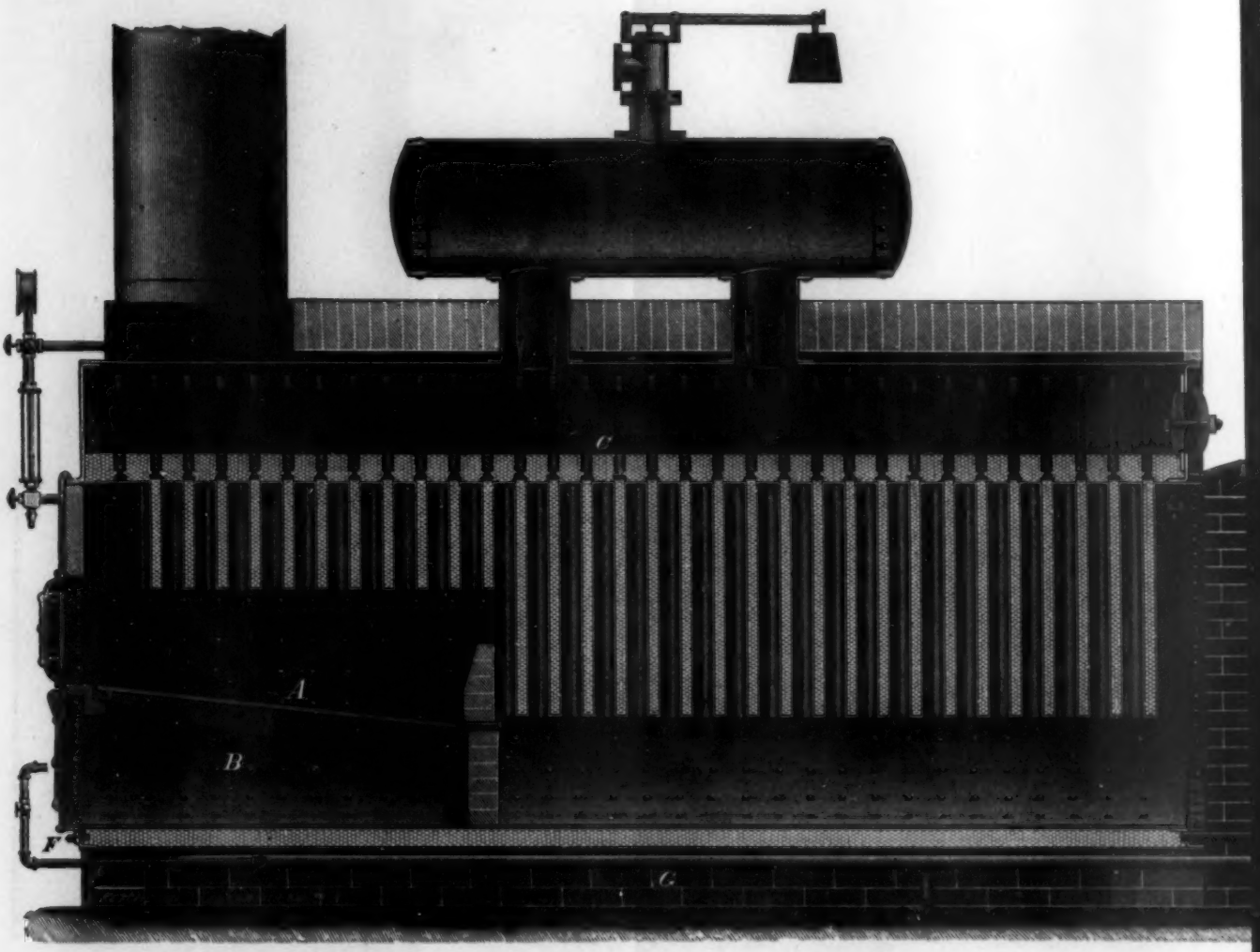
The thanks of the committee are due to Messrs. C. W. Asbury, H. E. Asbury, H. H. Cooke, C. G. Davis, W. C. Lusson, C. S. Martinez, R. M. W. Ridington, G. A. Sulzer, R. Welch, C. M. Wisman, A. H. Wood, W. Henry, of the Spring Garden Institute, who rendered very valuable service in taking data.

In making the tests, steam was first raised to the required pressure, when the fires were quickly drawn and the ash-pit cleaned, and a record kept of all wood, coal and water used from that time forth. The test was considered as commencing at the time the boiler made steam after the second fire was built.

At the end of the test, the coal weighed and unused was subtracted from the coal account—the coal unburnt in the furnace also being returned to that account—the ashes and unburnt coal being weighed dry as soon as possible after drawing.

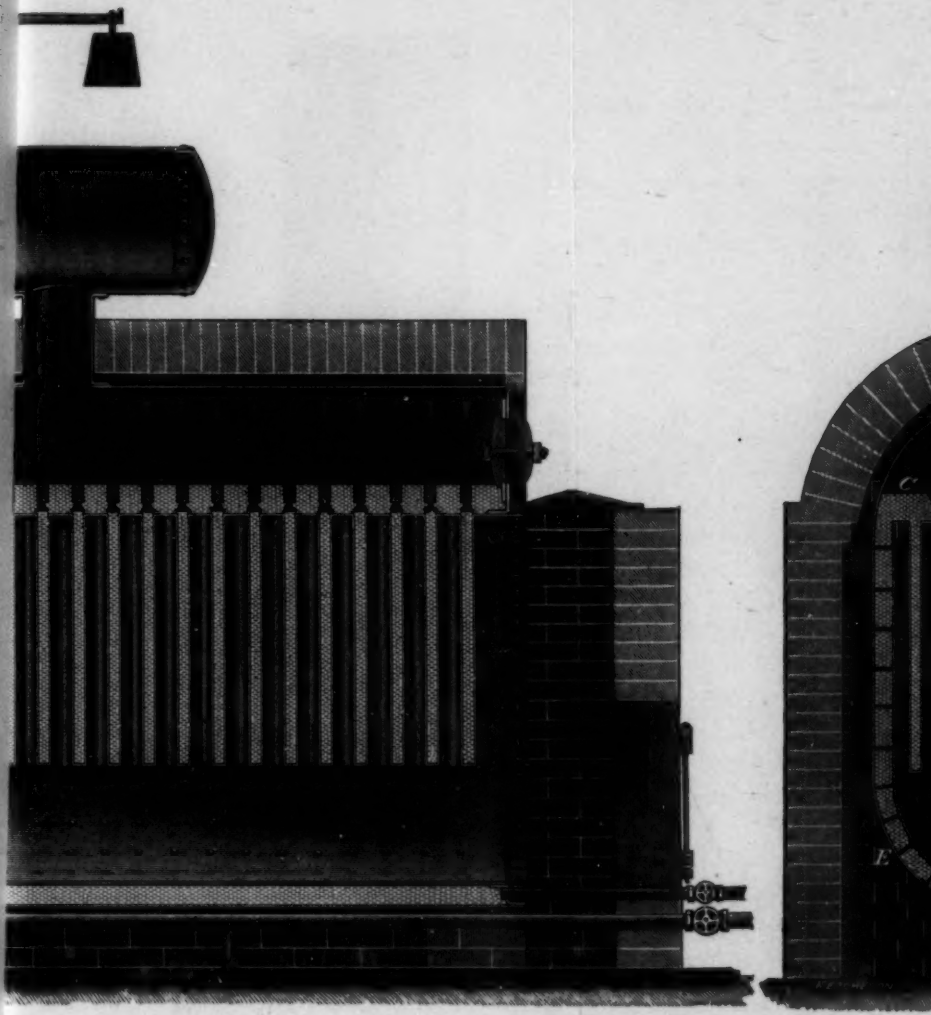
The wood used was found about the Exhibition building, and its value as combustible taken as 0 3 of its weight. The steam from the boiler was blown into the atmosphere through a safety valve on the main steam-pipe, and the smoke-stack was furnished with a steam jet. A record was kept of the position of damper, the blower, firing, etc.

The height of water in the gauge-glass was noted at the beginning of test, was kept as nearly as possible at that point during the test, and at the end was brought exactly to it.



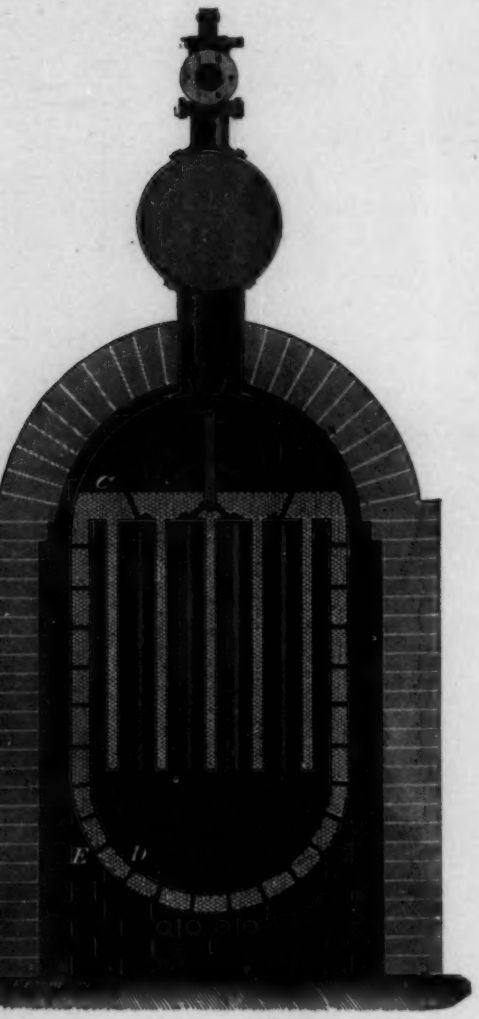
THE KINGSLEY BOILER.

Grate surface, 4 feet 6 inches by 2 feet 8 inches—12 square feet.
Heating surface, water on one side, 592·03 square feet.
Heating surface, steam on one side, 52·97 square feet.
Total heating surface, 645·00 square feet.

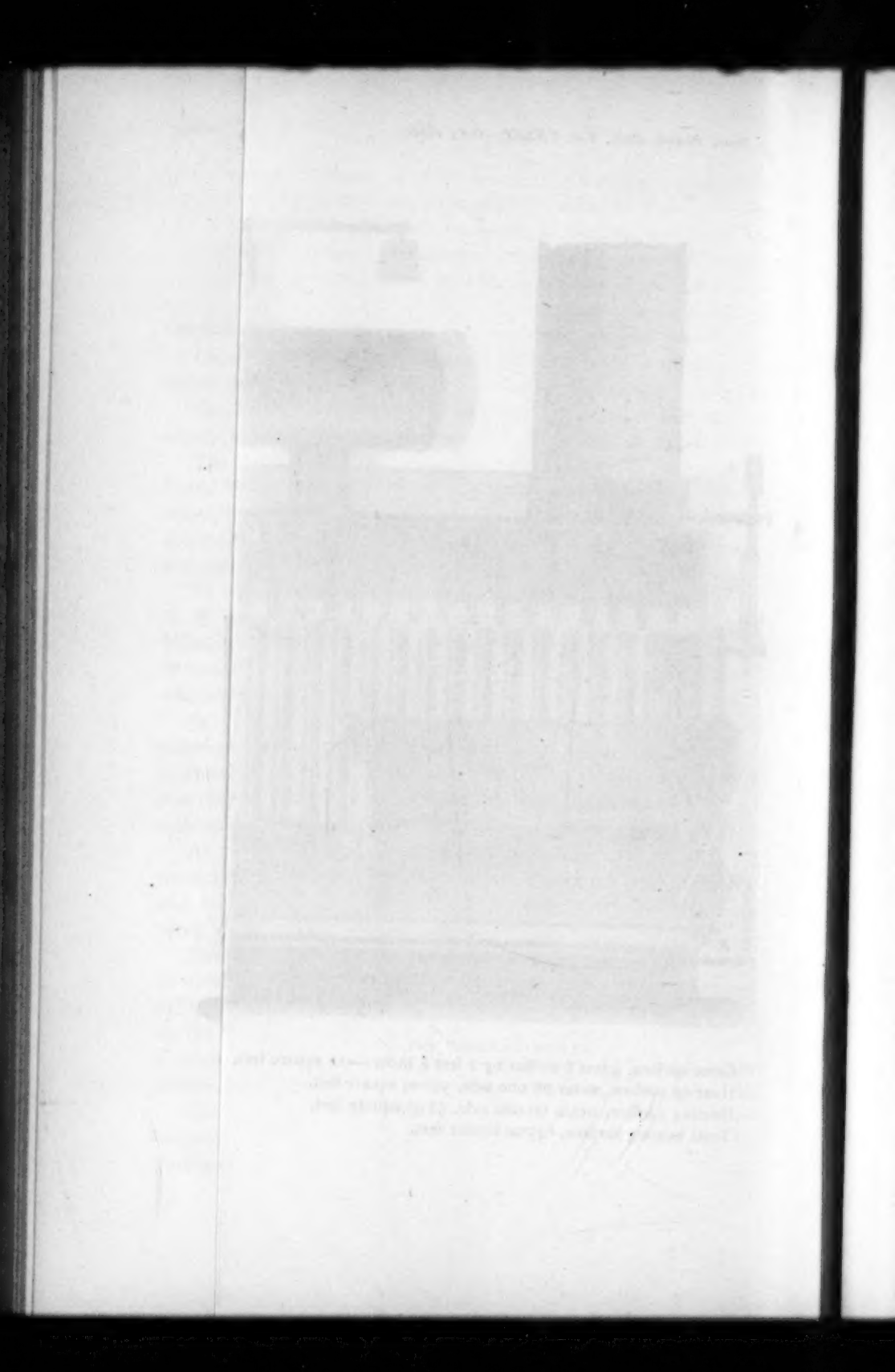


THE KINGSLEY BOILER.

Ratio of grate to heating surface, 1 to
Height of stack from grate-bars, 47 fe
Diameter of stack, 24 inches.



surface, 1 to 53·95.
te-bars, 47 feet.
ches.



The coal used was bituminous (Powelton steamship coal), and contained some moisture. A quantity was spread over a boiler and dried, the amount of moisture determined, and allowance made for the same. The coal was weighed in barrels on platform scales, from which it was dumped into a separate box, and used as occasion required.

The water was contained in two tanks, each on a scale, the suction of the feed-pump being arranged to draw alternately from each tank. These were weighed full and empty, and the difference taken as the weight of water used from each. The tank scales were very close to the boiler. The feed-water was heated by a steam jet, the weight being taken after the jet was turned off. The surface evaporation from the tanks was determined, and deducted from the total weight of water used.

No allowance was made for loss of heat in feed-water between tanks and boiler.

The temperatures of the feed-water, steam, smoke-stack, atmosphere, and the readings of the steam-gauge and chimney-draft were taken at short intervals, and the means calculated.

The draft in stack was obtained by means of a glass U-tube half full of water, one leg being connected with the inside of the stack, and the other with the atmosphere.

The temperatures of the steam and stack were taken from thermometers immersed in oil, which was contained in wrought-iron pipes leading into the steam-drum and stack—the steam-thermometer standing vertically, and the thermometer in stack at about 60° from the horizontal.

The height of the barometer was obtained from the United States Signal Office in Philadelphia.

The quality of the steam was determined by a barrel calorimeter. Steam was led by a well-felted pipe to a wooden barrel partly filled with water, the weight and temperature of which were known—the resulting weight and temperature of the water were taken as well as the pressure by steam-gauge. The water was stirred during the operation by a propeller revolving in a barrel. The following formula was used:

$$x = \frac{w_1 g_1 - w g - S H_1}{S g_2 - S H_1}$$

x = weight of water in one pound of steam;
w = weight of cold water;
w_1 = weight of cold water and condensed steam;
g = heat units corresponding to temperature of cold water, counting from zero F.;
g_1 = heat units corresponding to temperature of mixture, counting from zero F.;
S = weight of steam condensed;
H_1 = total heat of steam at pressure in boiler from zero F.;
g_2 = sensible heat units corresponding to pressure of steam.

After the test, one short and one long tube, which are easily removed, were taken from the boiler and cut near their lower ends. The water poured from them was clear till near the bottom, when it became slightly muddy. In the bottom of the short tube, and for about three inches up its sides, was a thin scale (about $\frac{1}{64}$ inch).

The scale in the long tube was similar, with the addition of some fine granules; otherwise, the tubes were perfectly clean. The boiler had been running for about seven weeks.

TEST OF NOVEMBER 6, 1885.

Fire drawn at 8·22 A. M. New fire started at 8·26 A. M.
Steam forming at 8·32 A. M.
Test ended, 6·22 P. M.
Duration, 9 hours 50 minutes.

To change one pound of water at 166·79° to steam at 307·71° requires 1206·96 — 167·22 = 1039·74 units of heat, and as it takes 965·7 units of heat to change one pound of water at 212° to steam at 212°, one pound of water at 307·71° will require as much heat as 1·0767 pounds from and at 212°.

Pounds of wood used during test,	70·00
Pounds of coal used during test,	2205·29
Ashes,	196·50
Combustible—from coal,	2008·79
Combustible—from wood,	21·00
Combustible—total,	2029·79
Pounds of water evaporated under the conditions,	20423·50
Pounds of water evaporated from and at 212°,	21989·98
Pounds of water evaporated per hour under the conditions,	2076·96
Pounds of water evaporated per hour from and at 212°,	2236·89
Pounds of coal used per hour,	224·27

Pounds of coal used per hour per square foot of grate,	18·69
Pounds of water evaporated per pound of coal, under the conditions,	9·261
Pounds of water evaporated per pound of coal, from and at 212°,	9·971
Pounds of water evaporated per pound of combustible, under the conditions,	10·061
Pounds of water evaporated per pound of combustible, from and at 212°,	10·834
Mean temperature of feed-water,	166·79°
Mean temperature of steam,	307·71°
Mean temperature of smoke-stack,	227·13°
Mean temperature of atmosphere,	70·90°
Mean pressure of steam,	68·59
Mean barometer,	30·12 inches.
Mean chimney draft in inches of water,	0·33
Mean position of damper,	0·83 open.

Blower in use about two hours. Weather cloudy.

QUALITY OF STEAM.

8·45 A. M., steam contains 0·8 per cent. water.
10·45 A. M., steam contains 1·4 per cent. water.
12· M., steam dry.
1· P. M., steam superheated 7·06°.
2· P. M., steam contains 5·9 per cent. water.
3· P. M., steam superheated 20·85°.
4· P. M., steam contains 1·0 per cent. water.
5· P. M., steam superheated 40·28°.
6· P. M., steam superheated 3·97°.

TEST OF NOVEMBER 7, 1885.

Fire drawn at 8.14 A. M. New fire started at 8·19 A. M.
Steam forming at 8·20 A. M. Furnace front cracked at 11·20 A. M.
Test ended at 6·25 P. M.
Duration, 10 hours 5 minutes.

To change one pound of water at 164·39° to steam at 309·71° requires 1207·56 — 164·80 = 1042·76 units of heat. As it takes 965·7 units to change one pound of water at 212° to steam at 212°, one pound of water at 309·71° will take as much heat as 1·0798 pounds from and at 212°.

Maker's rating of boiler,	90 HP.
Pounds of wood used during test,	76·5
Pounds of coal used during test,	2985·25
Pounds of ashes,	305·13
Pounds of combustible used—from coal,	2680·12

Pounds of combustible used—from wood, . . .	22·95
Pounds of combustible used, total, ...	2703·07
Pounds of water evaporated, ...	25915·37
Pounds of water evaporated from and at 212°, .	27983·42
Pounds of water evaporated per hour under the conditions, ...	2570·10
Pounds of water evaporated per hour from and at 212°, ...	2775·24
Pounds of coal used per hour, ...	296·06
Pounds of coal per hour per square foot of grate,	24·67
HP. of boiler (basis of thirty pounds evaporation per hour from and at 212°, ...	92·51
Pounds of water evaporated per pound of coal under the conditions, ...	8·681
Pounds of water evaporated per pound of coal from and at 212°, ...	9·374
Pounds of water evaporated per pound of combustible under the conditions, ...	9·587
Pounds of water evaporated per pound of combustible from and at 212°), ...	10·352
Mean temperature of feed-water, ...	164·39°
Mean temperature of steam, ...	309·71°
Mean temperature of smoke-stack, ...	281·04°
Mean temperature of atmosphere, ...	73·40°
Mean pressure steam, lbs., ...	69·40
Mean barometer, inches, ...	30·06
Mean chimney draft in inches of water, . . .	·66

Blower in use throughout the test. Weather cloudy, with rain for two hours. Damper wide open throughout test. Feed-water muddy.

QUALITY OF STEAM.

9· A. M., steam contains 2·8 per cent. water.
10· A. M., steam superheated 17·07°.
11· A. M., steam contains 8·4 per cent. water.
12· M., steam contains 7·8 per cent. water.
1· P. M., steam contains 2·4 per cent. water.
2· P. M., steam contains 4·3 per cent. water.
3· P. M., steam contains 1·9 per cent. water.
4·15 P. M., steam superheated 202·83°.
5·15 P. M., steam contains 2·4 per cent. water.
6·15 P. M., steam contains 0·6 per cent. water.

The sub-committee recommends the award of a SILVER MEDAL *with further reference to the Committee on Science and the Arts of the* FRANKLIN INSTITUTE.

(*To be continued.*)

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FLOW OF METALS IN THE DRAWING-PROCESS.

BY OBERLIN SMITH.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 29, 1886.*]

LADIES AND GENTLEMEN:—In introducing the subject upon which I have been asked to address you this evening, "The Flow of Sheet-Metals in the Drawing-Process," I will refer briefly to *flowing*, in general, and to this motion as it occurs in various metallic and other solid materials. Webster defines "flowing" as moving "with a continual change of place among the particles or parts, etc., as in a liquid," and to many people the idea is connected only with liquids and other fluids. A further flow of the brain molecules which are supposed to represent their inner consciousness, however, will soon show them that such motion is a very common phenomenon in all the events transpiring in daily life before their eyes, both in semi-fluids and in solids; also, that this flow may be *elastic* or *non-elastic*.

Common instances of elastic flow may be found in the wonderful stretching of a piece of india-rubber to perhaps ten times its normal length, and its indignant return to exactly its original form;